Series II, Volume 2 September 5, 1957 Number 6

BULLETIN

OF THE

AMERICAN PHYSICAL SOCIETY

INCLUDING THE

PROGRAMME OF THE

1957 SUMMER MEETING IN THE WEST

AT

BOULDER, COLORADO

September 5–6–7

PUBLISHED BY THE AMERICAN PHYSICAL SOCIETY, COLUMBIA UNIVERSITY, NEW YORK 27, NEW YORK
EIGHT ISSUES EACH YEAR

BULLETIN

of the

AMERICAN PHYSICAL SOCIETY

Published eight times per year

Subscription price: $5.00 per year

Single copies: $1.00 each

The Bulletin of the American Physical Society is published eight times a year, once in January, twice in March, once in April, once in June, once in September, once in November, and once in December, at Prince and Lemon Streets, Lancaster, Pennsylvania. Correspondence should be addressed to American Physical Society, Columbia University, New York 27, New York.

Entered as second class matter, December 27, 1949, at the post office at Lancaster, Pa., under the Act of August 24, 1912.

Acceptance for mailing at a special rate of postage provided for in paragraph (d-2), Section 34.40, P. L. & R. of 1948, authorized Nov. 30, 1948.

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September 5, 1957 Series II, Vol. 2, No. 6

BULLETIN

OF THE

AMERICAN PHYSICAL SOCIETY

1957 Summer Meeting in the West, Boulder, Colorado, September 5–7, 1957

THE **1957 summer meeting on the Pacific Coast** will not take place on the Pacific Coast, but will be held on the campus of the **University of Colorado** in Boulder, on Thursday, Friday, and Saturday, **September 5, 6, and 7.** The Society has never met here before and, judging from the volume of the contributions to the program, this is a popular place to hold a meeting.

On requests for **University housing or information,** letters should be addressed to Mr. Clifford Yoder, Director of Men's Residence Halls, University of Colorado, Boulder. He will supply information about motels and hotels in the vicinity as well. All of Fleming Hall is being reserved for this meeting and as much of Willard and other residence halls as are needed will be used. The rates in the residence halls are $7.50 per person in a double room for the three nights and $12 per person in a single room for the three nights. It would be convenient if reservations could be made before August 29, but, of course, all requests for accomodations will be filled. All double rooms have twin beds and children can be accommodated in the dormitories. No private baths are available in the residence halls, but central bath facilities are available conveniently on each floor. Maid service is provided. Check-out time will be 3:00 P.M. on Saturday, September 7, except for those making the trip to Climax on Sunday, in order to accommodate students coming in for the Fall Semester. Special arrangements will be made for these people. There is no direct railroad or air connection to Boulder, since Denver is just 27 miles away, via a toll road. There is frequent bus service between Denver and the campus, but a warning is in order that the service ceases between midnight and 6 A.M. the following morning. For this reason, the registration desk in the University Memorial Center will be staffed on Wednesday late afternoon before the meeting for those people who will necessarily arrive on Wednesday afternoon.

Registration will be in the University Memorial Center in the West Ballroom. The sessions will all be held nearby. There will be tables set up for registration on Wednesday, September 4, from about 4:30 on. There will be a bulletin board and message center, and lounges are close by where coffee may be served. City, State, and University maps and travel information will be available near the registration desk. Anyone who writes in for information for rooms will have a registration card made up for him in advance. All University reservations will be available at the desk. The registration fee remains at $1.00. Tickets for the banquet will be sold at the registration desk until 1 P.M. Friday. The price is $3.00.

The **banquet of the Society** will take place at 7:30 Friday night at the University Memorial Center. The principal speaker will be Dr. A. V. Astin, the Director of the U. S. Bureau of Standards. The title of his talk will be "Scientists and Public Responsibility." Professor J. W. Beams, the Vice-President of the Society, will be the presiding officer.

The program consists of **one hundred and twenty-two contributed papers** and **thirty invited papers.** The usual parallel sessions are in order, but with no more than three at any one time. While this is the largest number of papers at a summer meeting in recent years, it has still been possible to arrange them so that there is no major conflict in subject matter. These arrangements for the benefit of the Society have been made by Professor A. B. Weaver, Chairman of the Local Committee. The program has been arranged with the help of Professors J. R. Pellam, J. O. Rasmussen, B. J. Moyer, J. R. Zacharias, B. E. Cohn, D. A. Lind, and Dr. E. Burstein.

On Thursday evening a **chuckwagon supper** will be held on top of Flagstaff Mountain. Transportation to the mountain top after the sessions will be provided for those who need it, and tickets for the supper, costing $1.50, will be sold at the registration desk. Reservations for the chuckwagon should be made by September 3 and by mail if necessary. Later reservations may not be accepted. During the

meetings the National Bureau of Standards will conduct tours of its laboratories. Also, during the meetings, arrangements will be made for those who would like to visit the installations at Mount Evans and Echo Lake. On Sunday there will be a tour of the High Altitude Observatory of the University at Climax for those wishing to spend the extra day in Boulder.

There will be a **ladies' program** which will include tours of local points of interest and a tea. Information about this will be available at the ladies' desk.

Meal Schedule

September 4: Dinner—6 to 7—Indian Grill

September 5: Breakfast—7 to 9—Indian Grill
Luncheon—12 to 1:30—Buffet in U.M.C. East Ballroom (or alternate for those who prefer cafeteria, Indian Grill)
Dinner—6:30—Chuckwagon on Flagstaff Mountain (or 6:00 in Indian Grill)

September 6: Breakfast—7:30 to 8:30—Indian Grill
Luncheon—12 to 1:30—Buffet in U.M.C. East Ballroom (or Indian Grill)
Banquet—6:00—U.M.C. Ballroom

September 7: Breakfast—7:30 to 8:30—Indian Grill
Luncheon—12 to 1:30—Indian Grill

It will be necessary to make reservations for the buffet meals, for the Chuckwagon and for the Banquet. The individual reservations can be made for each buffet. The price will be $1.50 for each buffet and for the Chuckwagon and $3.00 for the Banquet. The local committee will provide transportation for the Chuckwagon, but help will be welcomed in this regard from any members who have their own cars.

Post-deadline papers of sufficient importance to warrant their inclusion in a special supplementary program will be considered by the Local Secretary if the abstracts are received no later than Friday, August 30, at the office of the Local Secretary for the Pacific Coast (see address below). These papers will be presented following sessions that will be designated on a blackboard in the lobby of the University Memorial Center.

W. A. NIERENBERG
Local Secretary for the Pacific Coast
Department of Physics
University of California
Berkeley 4, California

EPITOME OF THE 1957 BOULDER MEETING

(Personal names are those of invited speakers.)

Thursday Morning

9:30 A. Low-energy nuclear physics; Harvey, Manley, Johnson, Boehm. Memorial, Forum.*

9:30 B. Solid state I. Physics 104.

9:30 C. Spectroscopy and shock waves. Hellems 111 E.

Thursday Afternoon

1:30 D. Low-temperature physics; Powell, Cooke, Ambler, Vinen. Memorial, Forum.*

1:30 E. Nuclear physics. Physics 104.

1:30 F. General physics. Hellems 111 E.

Thursday Evening

6:30 Chuckwagon Dinner on Flagstaff Mountain.

Friday Morning

9:00 G. Atomic clocks and microwave spectroscopy; Zacharias, Essen, Reder, Dicke, Dehmelt. Music Auditorium.

9:30 H. Neutron and electron physics. Memorial, Forum.*

Friday Afternoon

2:00 I. Cosmic rays; Reynolds, Fretter, Ney, Singer. Memorial, Forum.*

1:30 J. Theory; Judd. Physics 104.

1:30 K. Solid state II. Hellems 111 E.

Friday Evening

7:30 Banquet of the American Physical Society; Astin. University Memorial Center, Ballroom.

Saturday Morning

9:00 L. High-energy physics; Schneps, Telegdi, Ticho, Bludman. Memorial Center, Forum.

9:00 M. Atomic and nuclear resonance. Physics 104.

Saturday Afternoon

1:00 N. Cyclotrons; Boyer, Putnam, Allen, Kraushaar. Memorial Center, Forum.

1:00 O. Solid state physics; Burgess, van Vliet, North, Brophy. Physics 104.

1:00 P. Mesons and cosmic rays. Hellems 111 E.

Sunday

Tour of High Altitude Observatory at Climax.

* The Forum Room of the University Memorial Center.

PROGRAMME

THURSDAY MORNING AT 9:30

Memorial Center, Forum

(J. O. RASMUSSEN, presiding)

Invited Papers on Low-Energy Nuclear Physics

A1. Nuclear Reaction Mechanisms in the Heavy Elements. B. G. HARVEY, *Radiation Laboratory, University of California, Berkeley.* (30 min.)

A2. Recent Work in Fission. J. H. MANLEY, *Los Alamos Scientific Laboratory.* (30 min.)

A3. Low-Temperature Nuclear Orientation Experiments. C. E. JOHNSON, *Clarendon Laboratory, Oxford University, England.* (30 min.)

A4. Experiments on Beta Decay and Beta-Decay Interactions. FELIX BOEHM, *California Institute of Technology.* (30 min.)

THURSDAY MORNING AT 9:30

Physics 104

(R. B. SCOTT presiding)

Solid State I

B1. Melting Points of Separated Lithium Isotopes.* J. A. CRAWFORD AND D. J. MONTGOMERY, *Michigan State University.*—As part of a program exploiting isotopic mass as a probe for solid-state investigations, a preliminary determination of the melting points of natural lithium and of its separated isotopes† was made by a melting-wire technique. The samples were prepared by extruding wires from a steel die at room temperature. The following results were obtained for the melting point in °C: Li^6(99.3% Li^6, 0.7% Li^7), 180.0±0.1; Li^7(0.2% Li^6, 99.8% Li^7), 180.2±0.1; Li-natural (7.5% Li^6, 92.5% Li^7), 180.2±0.1. The difference in the melting points of the two isotopes in °C was found to be 0.24±0.04, an amount smaller by a factor of ten than that estimated on the Lindemann theory.

* Supported in part by the U. S. Atomic Energy Commission.
† We are indebted to the Stable Isotopes Division, ONRL, for supplying and analyzing the enriched samples, and in particular to Dr. P. S. Baker for his advice and assistance.

B2. Electrical Resistance of Separated Lithium Isotopes.* D. D. SNYDER,† R. G. LEFFLER, AND D. J. MONTGOMERY, *Michigan State University.*—The electrical resistance of specimens of separated lithium isotopes‡ was measured from 295°K to 20°K with a precision Kelvin double bridge. The samples consisted of 30-cm lengths of wire extruded through a die of 1-mm diameter. At 77°K the Li^6 was found to have a resistance, normalized to 295°K, about 10% lower than that of Li^7, in agreement with the predictions of the Bloch-Grüneisen theory.

* Supported by the U. S. Atomic Energy Commission and by the Office of Ordnance Research.
† Present address: General Motors Research Staff, Detroit, Michigan.
‡ Kindly supplied by the Stable Isotopes Division, ONRL.

B3. Evidence in Support of Small Tammann Constants. R. C. SILL,* *Stanford Research Institute.*—Reported values for the Tammann constant k lie in the range $(0.3\text{–}0.5)\times10^{-4}$ cm °C, representing large differences in solid and liquid surface tensions.[1] For myristic and stearic acids where $\sigma_L = 28.9$ ergs/cm², $k(MA) = 0.30\mu$°C, giving $\sigma_S(MA) = 118$ ergs/cm², and $k(SA) = 0.45\mu$°C, giving $\sigma_S(SA) = 172$ ergs/cm². Hence $\sigma_S(MA) = 4.1\sigma_L(MA)$ and $\sigma_S(SA) = 5.9\sigma_L(SA)$. If one assumes σ_L and σ_S proportional to their respective heats of evaporation[2,3] values for σ_S/σ_L for 45 materials[4] range from 1.018 to 1.31. Using heats of evaporation for myristic and stearic acids, one finds $\sigma_S/\sigma_L \cong 1.4$. X-ray and other studies of structure of solids and their melts show strong similarity at melting temperatures suggesting ratios of σ_S/σ_L near unity. Symmetric molecules should have ratios nearest unity; polar molecules farthest from unity. It is suggested that reported Tammann constants may contain systematic errors due to effects of the confining surfaces used to form the test cells, and that true Tammann constants may be about $\frac{1}{10}$ as great, giving $\sigma_S(MA) \cong 38$ ergs/cm² and $\sigma_S(SA) \cong 43$ ergs/cm².

* Now at New Mexico Institute of Mining and Technology.
[1] R. C. Sill and A. S. Skapski, J. Chem. Phys. **24**, 644–651 (1956).
[2] But see J. H. Hildebrand and R. L. Scott, *Solubility of Nonelectrolytes* (Reinhold Publishing Corporation, New York, 1950), p. 401.
[3] And particularly A. S. Skapski, Acta Metallurgica **4**, 576–582 (1956).
[4] J. C. Slater, *Introduction to Chemical Physics* (McGraw-Hill Book Company, Inc., New York, 1939), p. 259.

B4. Elastic Vibrations of Quartz.* KOZABURO MIYAKAWA, WESTON E. BOULTON, AND LOUIS R. WEBER, *Colorado State University.*—A new derivation of the equations of elasticity for quartz crystal has been obtained, assuming that the potential energy of a unit cell is determined only by the relative displacement between unit cells. All contributions of surrounding unit cells to the potential energy of the concerned unit cell are considered in local spherical coordinates with the origin at the unit cell. After deriving expressions for force and using a transformation of coordinates, expressions in Cartesian coordinates are obtained. The conventional equations result if the potential energy is of the quadratic form in relative displacements. It is noticed that the equations for a quartz crystal consist of spherically, centroidally, and trigonal-holoaxially symmetric components. Our recent experiment that undesirable overtones are extremely suppressed by limiting circular electrodes for AT circular plates and Shaw's[1] report of strong excitation of axially symmetric modes,

together with the above result of derivation, suggest a new method of approach to solutions in elastic vibrations.

* This work is supported by James Knights Crystal Company, Sandwich' Illinois.
[1] E. A. Shaw, J. Acoust. Soc. Am. 24, 457 (1952).

B5. Piezoelectric and Dielectric Characteristics of $BaTiO_3$ Single Crystals. A. H. MEITZLER AND H. L. STADLER, *Bell Telephone Laboratories, Inc.*—The dielectric and piezoelectric constants of *c*-domain $BaTiO_3$ single-crystal plates are sensitive functions of their net polarization when determined from capacitance measurements using ac voltages much smaller than the coercive voltage. It has been reported[1] that the dielectric constant at frequencies below thickness resonance has a minimum at zero net polarization, and our measurements confirm this result. On the other hand, at frequencies above the fundamental thickness resonant frequency, the dielectric constant has a distinct maximum at zero polarization. The dielectric constant varies about 30% from minimum to maximum in both frequency ranges. In both ranges the conductance is maximum at zero polarization. The piezoelectric output voltage of a $BaTiO_3$ single crystal subjected to a constant amplitude recurrent strain pulse has been measured and found to be approximately proportional to its net polarization. However, departures from linearity are observed. If piezoelectric output voltage is plotted as the ordinate and net polarization as the abscissa, one finds a hysteresis dependence. In addition, two other types of departure from proportionality are observed which vary from crystal to crystal.

[1] M. E. Drougard and D. R. Young, Phys. Rev. 94, 1561 (1954).

B6. Oxygen Impurity in Silicon Single Crystals. A. SMAKULA AND J. KALNAJS, *M.I.T.*—Silicon crystals grown in fused silica crucibles have a smaller lattice constant than those grown by the floating-zone method. No difference in density, as measured by hydrostatic weighing, has been detected up to the 5th decimal place. This indicates that oxygen is built in substitutionally into the silicon lattice. The concentration of oxygen computed from the lattice contraction is of the order of $10^{18}/cm^3$, in agreement with chemical and optical determinations.[1] The 9-μ absorption band of heat-treated silicon crystals contaminated by oxygen exhibits five maxima which coincide with the absorption maxima of quartz. The integrated intensity of the absorption in the 9-μ region before and after heat treatment remains within 10% constant. It is concluded that in the heat treatment SiO_2 is formed.[2]

[1] Kaiser, Keck, and Lange, Phys. Rev. 101, 1264 (1956).
[2] W. Kaiser, Phys. Rev. 105, 1751 (1957).

B7. Magnetoresistance of Bismuth Single Crystals at High Fields. WILLIAM F. LOVE AND JAMES C. HASLETT, *University of Colorado.*—Apparatus for the production of pulsed magnetic fields has been developed for investigating magnetic effects in solids at low temperatures. The fields are produced by discharging the energy stored in the capacitors of a Westinghouse spot welder power supply into a solenoidal magnet. The energy may be discharged into the magnet either through a step-down transformer or directly from the power supply through a triggered spark gap. With the transformer the maximum fields attained are 165 kilogauss with a discharge time of 25 milliseconds. When the direct discharge method is used, the fields produced are of the order of 350 kilogauss with a discharge time of 250 microseconds. Initial investigations are being carried out on the magnetoresistance and magnetic susceptibility of bismuth single crystals. Depending on the orientation of the crystal with respect to the field, the magnetoresistance ratio R_{TH}/R_{TO} at 165 kilogauss is found to vary from 10 to 5000 at liquid N_2 temperatures. Additional work on the magnetoresistance of bismuth is being done at liquid helium temperatures.

B8. Surface Tension of Titanium, Zirconium, and Hafnium. A. W. PETERSEN,* H. KEDESDY, P. H. KECK,† AND E. SCHWARZ,‡ *U. S. Army Signal Engineering Laboratories.*—The surface tension of liquid Ti, Zr, and Hf at their melting points was measured in pure argon atmosphere by the drop-weight method. A constant field induction coil to melt the sample rod tip was used. The average values obtained were 1407, 1410, and 1477 dynes/cm respectively and are thought to be good within $\pm 3\%$.

* Now with the University of Utah, Salt Lake City, Utah.
† Now with Sylvania Electric Products, Inc., Bayside, New York.
‡ Now with Convair, San Diego, California.

B9. Formation of Dislocation Walls in Corundum during Bending.* ROBERT J. SCHEUPLEIN AND PETER GIBBS, *University of Utah.*—It is observed by an etching technique[1] that the process of bending in the plane containing the *c*-axis produces pairs of dislocation walls in αAl_2O_3. Dislocations are relatively absent in the 10 μ space between them, and lattice curvature is opposite on the two sides. Polarized light reveals intense lattice strain. These walls can apparently serve as nuclei for fracture, and can be etched into macroscopic cracks. A similar phenomenon in metals would produce stress corrosion cracking.

* Supported by the Office of Naval Research.
[1] Bates, Cutler, Scheuplein, and Gibbs, Abstract B11, this Bulletin.

B10. Decoration of Dislocations in Corundum by Voids.* PETER GIBBS AND ROBERT J. SCHEUPLEIN, *University of Utah.*—It has been demonstrated experimentally that air quenching of α-Al_2O_3 from high temperature produces a band of macroscopic voids on the dislocation structure about 10μ below the surface. Theoretical interpretation suggests the existence of "vacancy clusters" in equilibrium in the heated solid. Gradients in temperature or vacancy density (as in sintering or Kirkendall diffusion) would thus also lead to cavitation on dislocations. An origin for thermal shock is suggested.

* Supported by the Office of Naval Research.

B11. Etching of Dislocations in Corundum.* J. LAMBERT BATES, IVAN B. CUTLER, ROBERT J. SCHEUPLEIN, AND PETER GIBBS, *University of Utah.*—Triangular etch pits about 1 micron across, corresponding to individual edge dislocations, have been observed in deformed specimens of aluminum oxide single crystals after about 5 minutes immersion in boiling phosphoric acid. Typical photomicrographs of the etched surfaces after flame polishing, deformation, and at various stages of polygonization have been taken.

* Supported by the Office of Naval Research.

B12. Complex Color Center in Corundum.* IVAN B. CUTLER J. LAMBERT BATES, AND PETER GIBBS, *University of Utah.*—The absorption peak in α-Al_2O_3 at 260 mμ found by Levy and Dienes[1] after pile irradiation has been detected at the center of untreated ½-inch Linde disks. The peak can also be produced spatially nonuniformly by heating in oxygen above 1300°C. Peak intensity saturates with heating time at about 10^{18} centers/cm^3. About 6 kcal/mole activation energy is required for production. The peak can be removed by heating in hydrogen. Heating in nitrogen has negligible effect. A complex center is suggested.

* Supported by the Office of Naval Research.
[1] Levy and Dienes, *Bristol Conference* (Physical Society, London, 1955), p. 256.

B13. Electrical Conductivity of Corundum.* ROSS N. TUCKER AND PETER GIBBS, *University of Utah.*—Electrical conductivity of α-Al_2O_3 single crystals has been studied between 20°C and 1400°C. At 20°C a field-dependent transient

of several seconds duration is found, corresponding to a charge density of about 10^9 electrons per cm^3 on the corundum-air interface. Between 300°C and 500°C pulses of about 10^8 electrons total, and seconds duration, are found upon heating, but not upon cooling, in water-saturated nitrogen. They are absent in dry nitrogen. The magnitude of these pulses implies that water desorption is a cooperative phenomenon. In both atmospheres the steady-state conductivity remains at a low, nearly constant value between 100°C and 400°C, has an exponential rise (with activation energy of about 1.7 ev) between 400°C and 700°C. Between 700°C and 900°C the conductivity shows a slight minimum. Above 900°C there is a second exponential rise with activation energy in the range of 2.2 to 2.8 ev.

* Supported by the Office of Naval Research.

B14. Growth of Tellurium Single Crystals by the Czochralski Method. T. J. DAVIES, *Honeywell Research Center* (introduced by K. C. Nomura).—Several Te crystals have been grown by the Czochralski technique. Weidel[1] has previously reported success in Germany by this method. Te purified by vacuum distillation was contained in a quartz-lined graphite crucible heated by an induction field in an H_2 atmosphere and single crystals were pulled at 2 and 5 cm per hour with 16 rpm crucible rotation. Temperature control to within ±0.15°C seemed entirely adequate. The seeds were oriented so that the growth direction of the crystal was parallel to the *C* axis. A necked-in seed dipping procedure seemed to be necessary and crystal size was limited by the physical weakness of the seed taper. The maximum size grown was 1.5 cm by 7.5 cm. Cleavage of the crystals exposed mirror-like (10$\bar{1}$0) planes and Laue x-ray studies indicated freedom from the small angle misorientations common to many Te crystals. Also, these crystals were free of the bubbles and cracks which permeate crystals grown by most other methods.

[1] J. Weidel, Z. Naturforsch **9a**, 697 (1954).

B15. Electrical and Other Physical Properties of Some Vitreous Selenides.* D. F. CLIFTON AND LEE GILDART, *University of Kentucky.*—Properties of the vitreous form of compounds of the Group Vb and Group VIb elements of the type A_2B_3 (mainly selenides) have been studies. The absence of small angle x-ray scattering shows the materials to be truly vitreous rather than microcrystalline. Structure, semiconducting behavior, tendency toward crystallization, softening temperature, and density are the properties considered.

* Supported by the U. S. Air Force through the Air Force Office of Scientific Research of the Air Research and Development Command.

THURSDAY MORNING AT 9:30

Physics 117

(W. A. RENSE presiding)

Spectroscopy and Shock Waves

C1. Optical Dispersion in NH_3 in the Infrared. S. H. KALMBACH,* R. L. KELLY,† AND R. R. ROLLEFSON, *University of Wisconsin.*—The index of refraction of NH_3 has been measured at 47 points in the spectral region from 1–17 microns and the results fitted to a Sellmeier dispersion curve. Strengths of the fundamental vibrations ν_2 and ν_4 (950 and 1627 cm^{-1}) were determined with an estimated error of 10%, but the effects of ν_1 and ν_3 (3337 and 3448 cm^{-1} were not separable with these data.

* Now at U. S. Naval Postgraduate School, Monterey, California.
† Now at Stanford Research Institute, Palo Alto, California.

C2. Lifetime of the $A^3\Sigma_u^+$ State of Molecular Oxygen. C. A. BARTH AND J. KAPLAN, *University of California, Los Angeles.**—The Herzberg oxygen bands, $A^3\Sigma_u^+ - X^3\Sigma_g^-$, appear with different vibrational intensities in the night airglow of the upper atmosphere and oxygen afterglows produced in the laboratory. If it is assumed that the excited molecules are produced by the same chemical reaction in the upper atmosphere as in the laboratory afterglow, the difference in vibrational populations is probably due to the difference in pressure of the two sources. Since the laboratory afterglow spectrum, pressure 2 mm Hg, has a lower vibrational "temperature" than the night airglow spectrum, an upper limit of 10^{-3} sec is placed on the lifetime of the A state of oxygen. The production of the Herzberg oxygen bands in the night airglow by the three-body recombination of oxygen atoms predicts a region of emission near 80 km, where the pressure is 10^{-3} mm Hg. The night airglow spectrum appears to be in rotational equilibrium giving a lower limit of 10^{-4} sec for the *A* state. Thus, the lifetime of the $A^3\Sigma_u^+$ state of oxygen appears to lie between 10^{-4} and 10^{-3} sec.

* Supported in part by the Geophysics Research Directorate, Air Force Cambridge Research Center.

C3. Infrared Spectrum of Trifluoroacetic Acid Vapor. R. E. KAGARISE, *U. S. Naval Research Laboratory.*—The infrared absorption of trifluoroacetic acid vapor in the 2 to 24 micron region has been studied as a function of temperature. At room temperature both monomer and associated molecules are present, while at 100°C the vapor is predominately monomeric. On the basis of the resulting intensity changes it has been possible to conclusively identify the bands due to the two species. A partial assignment of the fundamental modes of vibration has been made using these data and the previously reported spectrum of the deuterated acid. The heat of dissociation (ΔH) of the associated species has been determined from a quantitative study of the temperature dependence of the intensity of the OH stretching bands. The observed value of 13.7±0.4 kcal/mole agrees well with the values of 14.0 and 14.06 kcal/mole obtained from vapor density measurements.

C4. Experimental Photodetachment Cross Section of O_3^- in the Visible and Near Infrared.* DAVID S. BURCH, STEPHEN J. SMITH, AND LEWIS M. BRANSCOMB, *National Bureau of Standards.*—We have measured the photodetachment cross section for negative diatomic oxygen ions in the range of photon energies from 0.5 to 0.3 ev. No threshold for the reaction is observed within this energy range. The cross section is found to rise slowly from 3.8×10^{-20} cm^2 at photon wavelength 22 500 A, and then more rapidly to 2.5×10^{-18} cm^2 at 4200 A. The ions are extracted from a Fite discharge source operated with pure O_3 at a pressure of about 50 microns Hg and are found to have energies ~300 ev when leaving the anode aperture, this also being their energy during the photon-ion interaction. It is unlikely that the rotation-vibration populations are equilibrated at this energy. Although

lack of knowledge of these populations and of the shapes of the O_3^- potential curves precludes a complete analysis of the results, some inferences may be drawn concerning these problems. Assuming that O_3^- ions in the *D* region of the ionosphere have a population distribution similar to that of our laboratory ions, we have calculated a photodetachment rate of 0.44/sec/ion.

* Supported in part by the Office of Naval Research.

C5. Infrared Spectra of the Isotopic Nitrous Oxides. G. M. BEGUN AND W. H. FLETCHER,* *Oak Ridge National Laboratory.*—The infrared spectra of $N^{14}N^{15}O^{16}$, $N^{15}N^{14}O^{16}$, and $N^{15}N^{15}O^{16}$ have been observed from 2.5 μ to 20 μ using a model 112 Perkin-Elmer spectrometer. The frequencies of the three fundamental vibrational bands and eleven combination bands have been tabulated and compared with the known frequencies for $N^{14}N^{14}O^{16}$. Approximate zero-order frequencies have been calculated using the known anharmonic constants and isotopic relations and force constants for infinitesmal displacements have been computed.

* Consultant, Chemistry Department, University of Tennessee, Knoxville, Tennessee.

C6. Effects of Strong Shocks in Ferroelectric Materials. F. W. NEILSON, *Sandia Corporation* (introduced by G. W. Anderson).—The shock wave from a pellet of high explosive is passed without attenuation through an electroded element of polarized ferroelectric ceramic (e.g., barium titanate, lead zirconate-titanate). The shock forces a rapid depolarization of the element, thereby releasing the bound surface charge to flow through an external circuit connected to the electrodes. Typical outputs observed are the following: (1) ceramic: lead zirconate-titanate (Brush Electronics "PZT-1"); shape: disk 1.6-in. diam $\times$ 0.028-in. thickness; load: 0.1 ohm resistive; output: 4000 amperes peak, 600μ coulomb total charge, 0.3μ sec total duration. (2) ceramic: barium titanate; shape: hollow cylinder 1-in. diam. $\times$ 1-in. length $\times \frac{1}{4}$-in. wall, poled radially; load 5×10^4 ohm resistive; output: linear ramp to 60 kv at 3 μsec. It is proposed that the energy output is not the 2nd quadrant area of the *D-E* hysteresis loop but is transduced from the shock wave. This mechanism depends on the lowering of the Curie temperature at high pressures, and the increase of the Curie temperature with electric field in the direction of the initial polarization. Interesting one shot pulse generators using this principle have been constructed and will be described.

C7. Effects of Strong Shocks in Ferromagnetic Materials. G. W. ANDERSON AND F. W. NEILSON, *Sandia Corporation.*—The shock wave from a pellet of high explosive is passed without attenuation through one leg of a closed magnetized ferromagnetic core on which an output winding has been wound. The shock forces a rapid demagnetization of part of the core, thereby inducing a voltage in the winding. The generated voltage is predicted to be $V_g = NB_R vw \times 10^{-8}$ where N is the number of turns, B_R is the remanent magnetization (gauss), v is the shock velocity (cm/sec), and w is the width of the core (cm) in the direction perpendicular to B_R and v. Observations confirm this prediction within the experimental uncertainty of about 20%, mainly in v and B_R. A typical output is 46 volts-(turn)$^{-1}$ (cm of w)$^{-1}$. The output appears inconsistent with a release of energy previously stored in the ferromagnetic material, but can be explained by a transducer mechanism which removes energy from the shock and converts it into electrical energy. The mechanism proposed depends on the lowering of the Curie temperature at high pressures. The use of this principle as a technique in ferromagnetic research will be discussed.

C8. Experiments on Single and Colliding Shock Fronts.* R. W. HALES, E. J. EASTMOND, AND R. BAIRD, *Brigham Young University.*—Shock waves have been produced in cylindrical glass tubes after the method of Fowler.[1] Energy stored in 2 microfarads at 25 000 volts is discharged through various gases by means of an ignitron switch. The gas in the discharge, in expanding along an extension of the discharge tube, satisfies the conditions for the establishment of a shock front. A double discharge geometry is also used in which there are two cylindrical discharge regions connected in series electrically but separated physically along their common axis by an expansion region. The phenomena observed when the front reflects from the end wall of the expansion tube in the single discharge case will be compared to the phenomena observed when the front meets an equal oncoming front in the colliding front situation. Methods of analysis will be discussed.

* Supported by the U. S. Atomic Energy Commission.
[1] Fowler, Atkinson, and Lee, Summary Report, University of Oklahoma Research Institute, December 31, 1951.

C9. Observation of Stark Effect Broadening to Determine Ionic Conditions in Shock Tubes.* E. JOHN EASTMOND AND RICHARD W. HALES, *Brigham Young University.*—Stark broadening produced by random variable ionic fields as treated theoretically by Holtzmark has been recalculated and applied in the analysis of light from electrically initiated shocks in hydrogen. Time variation of H Balmer line contours at given positions in the shock tube has been observed using a photoelectric recording spectrograph. Experimental contours obtained at various times after the initial discharge and at various positions down the expansion tube have been compared with the Holtzmark curves calculated for H_β at effective field strengths from 60 to 220 kv/cm. Ion concentrations producing the observed effective fields have been calculated. Experimental methods will be described and the observed variations in ionization reported.

* Supported by the U. S. Atomic Energy Commission.

C10. Optical Absorption of Cl_2^- Molecule Ions in Irradiated Potassium Chloride.* P. H. YUSTER, C. J. DELBECQ, AND B. SMALLER, *Argonne National Laboratory.*—Känzig[1] has shown that potassium chloride, after long irradiation with x-rays at liquid nitrogen temperature, shows an electron spin resonance spectrum which can be attributed to Cl_2^- molecule ions. In the present investigation it has been found that KCl-Ag^+, KCl-Tl^+, and KCl-Pb^{++} crystals, after only very short irradiations with x-rays at liquid nitrogen temperature, also show the identical Cl_2^- resonance spectra reported by Känzig. Light bleaching experiments using polarized light coupled with electron spin resonance measurements have identified the optical absorption associated with the Cl_2^- molecule ions. This absorption consists of two bands which peak at 370 mμ and 750 mμ. The band in the red is of quite low intensity—about 3% of the intensity of the band in the ultraviolet.

* Based on work performed under the auspices of the U. S. Atomic Energy Commission.
[1] W. Känzig, Phys. Rev. **99**, 1890 (1955).

C11. Propagation of an Ionization Front in a Dilute Gas. STUART R. POTTASCH, *National Bureau of Standards, Boulder* (introduced by A. H. Shapley).—The problem considered is the following: what happens when ionizing radiation is incident on neutral hydrogen gas? The resultant effects depend on the amount and quality of the ionizing radiation, and the density of the gas. The results obtained by Kahn for the one-dimensional case are discussed and it is shown that this effect is one or two orders of magnitude greater than the ordinary radiation pressure. The results of this

discussion are applied to the astronomical problem of the bright rim structures in diffuse nebulae. A simple three-dimensional model is set up and it is shown that most of the rather extensive observations of bright rim structures may be accounted for on this basis, although the details of the evolution of the bright rims is somewhat uncertain. Future work calls for a more detailed, three-dimensional time-dependent study along the lines suggested by Kahn. One of the applications of this type of problem to be stressed in the future is the study of solar flares.

THURSDAY AFTERNOON AT 1:30

Memorial Center, Forum

(J. R. PELLAM presiding)

Invited Papers on Low-Temperature Physics

D1. Low-Temperature Transport Properties of Metals. ROBERT L. POWELL, *National Bureau of Standards.* (30 min.)

D2. Recent Work on Paramagnetics at Low Temperature. A. H. COOKE, *The Clarendon Laboratory, University of Oxford, England.* (30 min.)

D3. Experiments on Beta Emission from Polarized Cobalt Nuclei. ERNEST AMBLER, *National Bureau of Standards.* (30 min.)

D4. Experimental Evidence for the Existence of Quantized Vortex Lines in Helium II. W. F. VINEN, *The Mond Laboratory, University of Cambridge, England.* (30 min.)

THURSDAY AFTERNOON AT 1:30

Physics 104

(J. W. BROXON presiding)

Nuclear Physics

E1. Proton-Induced Reactions in Rhodium-103.* W. BLANPIED AND R. SHERR, *Princeton University.*—Angular distributions of (p,p'), (p,d), and (p,t) reactions in rhodium-103 have been studies at an energy of 18.8 Mev. The energy spectrum of the inelastic protons shows definite peaks, but the resolution was not sufficient to indicate individual levels. All protons between 5 and 14 Mev have an angular distribution strongly peaked below 30 degrees. Deuteron and triton spectra show peaks corresponding approximately in energy to ground-state transitions, although excited states up to 400 kev cannot be excluded. The "ground-state" deuteron angular distribution shows peaks at about 27 and 55 degrees; the triton angular distribution shows peaks at about 33, 65, and 105 degrees. This latter can be fit to a Butler curve by using a nuclear radius of $1.7(10)^{-13}A^{1/3}$ cm and by assuming that pairs of $d_{5/2}$ neutrons outside the closed shell in rhodium-103 may be found in an s state relative to the core. The yield of deuterons and tritons can be appreciable compared with protons; at 32 degrees and a particle energy of about 10.2 Mev, the relative yield of deuterons to protons is 1 to 2.5, while at about 8.2 Mev the yield of tritons to protons is 1 to 4.

* This work was supported by the U. S. Atomic Energy Commission and the Higgins Scientific Trust Fund.

E2. Lifetime Limit for the 3.57-Mev State of Li^6.* R. J. A. LEVESQUE AND S. M. SHAFROTH, *Northwestern University.*—Excited Li^6 nuclei were obtained by means of the $Be^9(p,\alpha)Li^{6*}$ reaction. The Northwestern 5-Mev electrostatic accelerator provided a beam of magnetically analyzed 2.56-Mev protons, which was used to bombard thick and thin beryllium targets, the latter being evaporated on tantalum backings. The 3.57-Mev gamma energy was measured in the 0° and 145 position with respect to the beam direction. The 2.615 Mev ThC'' gamma was used to give the energy calibration for each run. The gamma energy was determined by means of a conventional scintillation spectrometer consisting of a 2-in.×1¾-in. diameter sodium iodide crystal mounted on an RCA 6342 photomultiplier tube. The output pulses from the phototube were passed through a cathode follower, then amplified, and finally fed into a Radiation Counter Instrument Company 256 channel analyzer for amplitude analysis. The Doppler shift which was observed between 0° and 145° is about 1%. No difference outside of experimental error was obtained between the thin and thick target measurements. Preliminary calculations using this value of the shift indicate that the lifetime of this state must be shorter than 8×10^{-14} sec. Further experiments are in progress in order to reduce this figure. The effects of angular distributions of the recoil nuclei and slowing-down times will be discussed.

* This research was partially supported by a grant from the National Science Foundation.

E3. Energy Levels of F^{18}.* D. F. HERRING,† *University of Wisconsin.*—The $N^{14}(\alpha,\alpha)N^{14}$ differential cross sections previously reported[1] have been analyzed using the dispersion formalism to classify the energy levels of F^{18}. The results are summarized in Table I. The assignments in parenthesis were determined from a qualitative fit to the data. A detailed fit was not possible for these resonances because of either finite target thickness and beam energy revolution (narrow

TABLE I.

E_x (Mev)	J, π	Γ c.m.-kev	$\gamma\lambda^2 \cdots \frac{2\mu a}{3\hbar^2}$
6.260	(4,3,2$^-$)	<1.9	<1
6.275	(1$^+$)	<3	<0.03
6.584	(5,4,3$^+$)	<0.8	<1
6.662	...	<3	...
6.664	1$^-$	93±5	0.72
6.827	2$^-$	101±5	0.5
7.213	...	<4	...
~7.29	(3,2,1$^+$)	~62	...
~7.32	(≤6, ≥2$^-$)	~31	...

levels) or the influence of levels above the range of observation (last two levels).

* Supported by U. S. Atomic Energy Commission and the Wisconsin Alumni Research Foundation.
† Now at the Ohio State University, Columbus, Ohio.
[1] Herring, Chiba, Gasten, and Richards, Bull. Am. Phys. Soc. Ser. II, 1, 326 (1956).

E4. Radiative Capture of Alphas by N^{14}. W. R. PHILLIPS, *University of Wisconsin.**—The radiative capture of alpha particles in N^{14} has been examined in the energy range $E_\alpha = 1.5$ to 3.0 Mev. In addition to the two levels previously observed at $E_\alpha = 1.530$ and 1.617 Mev, two narrow resonances have been found at $E_\alpha = 2.350 \pm 0.004$, and 2.876 ± 0.006 Mev. These correspond to levels in F^{18} at 6.259 and 6.668 Mev, and the total widths of each of them are less than 4 kev. The 6.26-Mev level decays almost entirely to a level in F^{18} at 1.760 ± 0.020 Mev, with $\omega\tau_\gamma = 7.48 \pm 0.80$ ev. The decay of the 6.67-Mev level is more complex, but it also has a transition to the 1.76 level, with $\omega\tau_\gamma\tau_\alpha/\tau = 2.11 \pm 0.7$ ev. The 1.76 level has a ground-state transition, and also cascades via the level at 1.050 Mev. Angular distribution and correlation measurements at the $E_\alpha = 2.35$-Mev resonance are in progress, and these data together with those from the elastic alpha-scattering measurements at this energy provide information on the low-lying levels in F^{18}.

* Work supported by the U. S. Atomic Energy Commission and by the Graduate School from funds supplied by the Wisconsin Alumni Research Foundation.

E5. Direct Ionization Products from the Decay of Tritium in Tritiated Ethane.* DAVID C. HESS AND SOL WEXLER, *Argonne National Laboratory.*—The positive ions produced by the decay of the H^3 atom in $C_2H_5{}^1H^3$ have been studied in a 12-inch radius 60° deflector mass spectrometer. About 80% of the resulting ions have a mass number of 29, corresponding to $(C_2H_5)^+$. A small amount of mass 30 was observed which is assigned to $(C^{13}C^{12}H_5)^+$. The $(C_2H_3)^+$ and $(C_2H_2)^+$ ions were almost equally abundant, each comprising about 6% of the total ionization observed. Smaller amounts of $(C_2H)^+$ and $(C_2)^+$ were also measured. Less than 0.5% of the ions produced by the direct decay process were of mass 28, $(C_2H_4)^+$. No $(CH_n)^+$ ions were detected, suggesting that there is no violent disruption of the molecule as a result of the beta transition. No ions were detected in the mass 1–5 region, indicating that the charge stays with the heavier fragment. Unique features of the mass spectrometer are: 1. Multiple differential pumping. 2. A 90° spherical electric deflector to disperse the neutral beam of gas emanating from the source region. 3. A large source volume with a guide field to aid in extraction of the ions formed.

* Work performed under the auspices of the U. S. Atomic Energy Commission.

E6. Nuclear Forces in Meteoric Iron.* N. S. WALL AND ROY WEINSTEIN, *Massachusetts Institute of Technology.*—Observations of lack of conservation of parity in weak interactions suggest an asymmetry between left- and right-handedness in the universe. An alternative interpretation is that our local region of the universe has more particles of one-handedness than the other due to a statistical fluctuation. A difficulty with this suggestion is the question of how an almost 100% collection of one type of particles is achieved, due only to statistical fluctuation. An improbable but possible assumption is that the separation of nucleons of different handedness occurs not by chance, but due to a decrease in the strong forces between nucleons of different handedness. We have compared the elastic proton scattering of meteoric and terrestrial iron using 7.5-Mev terrestrial protons from the M.I.T. cyclotron, and iron from a sample of the Homestead meteorite. To within the experimental error of about 5% we found no difference in the elastic differential cross section at two angles corresponding to a maximum and a minimum in the relative angular distribution. The induced activities in the two samples were equal within the experimental error of 20%.

* This work was supported in part by the joint program of the Office of Naval Research and the U. S. Atomic Energy Commission.

E7. Gamma Rays from the Proton Bombardment of Natural Silicon.* L. W. SEAGONDOLLAR, J. A. WOODS, H. G. DE SOUZA, AND W. A. GLASS, *University of Kansas.*—Thick and thin targets of hyperpure, natural isotopic-abundance silicon (92.2% Si^{28}, 4.7% Si^{29}, 3.1% Si^{30}) were bombarded with monoergic protons over the energy range of 300 to 1400 kev. Gamma-ray yield curves were measured with a ½ in.×1 in. NaI crystal located approximately ½ in. from the targets. Resonances were observed at proton energies of approximately 326, 369, 414, 501, 622, 697, 776, 836, 943, 957, 979, 1202, 1205, 1291, 1327, and 1394 kev. With few exceptions, some of these resonances are in good agreement with those reported by Tangen,[1] Endt *et al.*,[2] Milani *et al.*,[3] and Broude *et al.*[4] Since the work of the latter three references was done on separated isotope Si^{29}, some of the resonances above which are previously unreported are believed at this time to be due to proton bombardment of Si^{28} and Si^{30}. Further identification is in process.

* Work partly supported by National Science Foundation.
[1] R. Tangen, Kgl. Norske Videnskab. Selskabs, Forh. Skrifter No. 1 (1946).
[2] Endt, Kluyver, and van der Leun, Phys. Rev. 95, 580 (1954).
[3] Milani, Cooper, and Harris, Phys. Rev. 99, 645(A) (1955).
[4] Broude, Green, Singh, and Willmott, Phys. Rev. 101, 1052 (1956).

E8. Elastic Scattering of Protons from Zn^{64} and Zn^{66}.* R. W. BOOM AND H. A. HOWE, *University of California at Los Angeles.*—The differential cross section for elastic scattering of 21.1-Mev protons from the U.C.L.A. cyclotron has been measured for Zn^{64} and Zn^{66}. The first minimum in the scattering cross section for Zn^{66} lies approximately 1° lower than Zn^{64} and the ratios of first maximum to first minimum are approximately 4. The scattered protons are detected by counting tracks in emulsions wrapped around a four inch diameter scattering chamber.

* Work supported by the joint program of the Office of Naval Research and U. S. Atomic Energy Commission.

E9. Elastic Scattering of Protons from Ca^{40} Observed at 180°.* R. H. DAVIS, F. W. PROSSER, JR., R. R. SPENCER, T. E. YOUNG, AND J. H. JOHNSON, *The Rice Institute.*—The differential cross section for the elastic scattering of protons from Ca^{40} has been measured at an angle of 180° with bombarding energies ranging from 1.0 to 4.7 Mev. To separate and identify the scattered protons, the yield was analyzed with a 180° magnetic spectrometer and the selected protons were detected with a CsI(Tl) scintillation counter. Targets 5 to 25 kev thick were fabricated by the evaporation of natural (97% Ca^{40})$CaCO_3$ onto carbon foils. Below 2 Mev, the

nonresonant yield closely followed Rutherford scattering. Isolated resonances were observed at 1.362, 1.673, 2.39?, 2.448, 2.508, 2.760, 2.953, 3.241, and 3.500 Mev. Above 3.5 Mev the strong overlapping of resonances precludes analysis without further data at other scattering angles. The width of the resonance at 2.448 Mev is 0.2 to 0.4 times the Wigner limit assuming l values of 0 and 1, respectively, and higher l values are prohibited. Consequently this level at 4.01 Mev in Sc^{41} is single particle in nature. The shape is qualitatively that of a $p_{1/2}$ level, but interference with nearby levels leads to some ambiguity. Where possible, comparison will be made between the levels found in Sc^{41} and those known in the mirror nucleus Ca^{41}.

* Supported in part by the U. S. Atomic Energy Commission.

E10. Proton-Deuteron Inelastic Scattering.* W. B. Doub,† B. T. Wright, *University of California, Los Angeles.*—Protons of energy 20.2 Mev are inelastically scattered from deuterium gas. The yield for the event, in which one of the proton products of energy greater than 2.63 Mev is scattered at an angle ϕ_6' with the incident beam and the other proton product of energy greater than 2.63 Mev is scattered at an angle ϕ_6'' with the incident beam, was measured. The pairs of angles $\phi_6'-\phi_6''$ for which the best statistics were taken were 20°−20°, 30°−30°, and 40°−40°. The resulting experimental laboratory cross sections were found to be constant within the quoted error of about 10%. The cross sections lie around 26 millibarns per (steradian)^2. A comparison of the experimental results was made with the theory of Frank and Gammel[1] who used the short range of nuclear forces to aid them in calculating certain Born approximation integrals. It was found by the author that the theoretical values of the cross section lay much closer to the experimental if a ratio of two integrals (assumed to be one by Frank and Gammel) was calculated explicitly and appended as a factor to the cross section.

* Work supported in part by Office of Naval Research.
† Now at Westinghouse Atomic Power Division, Pittsburgh, Pennsylvania.
[1] R. M. Frank and J. L. Gammel, Phys. Rev. **93**, 463 (1954).

E11. Elastic Scattering of 44.7-Mev Alpha Particles by Helium.* H. E. Conzett, G. Igo,† H. C. Shaw, and R. J. Slobodrian,‡ *University of California, Berkeley.*—The angular distribution of elastic scattering of 44.7-Mev alpha particles by helium has been measured in the beam of the Crocker Laboratory cyclotron. The experimental equipment has been described previously.[1] The experiment was carried out with a helium-filled scattering chamber, adequately collimating the incident beam and the detector solid angle. Energy spectra of scattered particles were obtained by pulse-height analysis of the output of a CsI scintillation counter. Data were taken at almost every degree for scattering angles from 6° to 45°; several additional points at angles larger than 45° served as a symmetry check. The shape of the angular distribution resembles the one taken by Graves at 30 Mev,[2] but the maxima and minima are considerably more pronounced. The major error is due to the uncertainty in the angular position of the counter, which is less than 0.1°. A phase-shift analysis of the results is in progress.

* This work was performed under the auspices of the U. S. Atomic Energy Commission.
† Stanford University, Stanford, California.
‡ Visitor from Comision Nacional de la Energia Atomica of Argentina.
[1] R. E. Ellis and L. Schecter, Phys. Rev. **101**, 636 (1956).
[2] E. Graves, Phys. Rev. **84**, 1250 (1951).

E12. Triton Cross Sections.* Nelson Jarmie and Robert C. Allen, *Los Alamos Scientific Laboratory.*—Because of a discrepancy in the measured values of the $D(t,\alpha)n$ cross section,[1,2] we have measured this and other cross sections with the apparatus used in studying the $T(t,\alpha)n,n$ reaction.[3] The preliminary results, good to about 5%, are given in Table I.

Table I.

Reaction	θ_{lab}	E_t(lab) Mev	$\sigma(\theta)_{lab}$ mb/sterad	$\sigma(\theta')_{cm}$ mb/sterad	Other results mb/sterad	Difference
$He^4(t,t)He^4$	30°	1.677	875	···	1060[a]	21%
$T(t,t)T$	30°	1.900	286	···	343[b]	20%
$D(t,\alpha)n$	30°	1.500	···	19.9	20.6[a]	3.5%
					24.2[d]	22%
$D(t,\alpha)n$	60°	1.500	···	19.3	20.0[a]	3.9%
					23.1[4]	20%

[a] See reference 4.
[b] See reference 5.
[c] See reference 1.
[d] See reference 2.

Our results agree with Bame[1] and are lower than the other measurements by about 20%. The measurements of Hemmendinger[4] and Holmand Argo[5] were done with essentially the same equipment as reference 2.

* Work performed under the auspices of the U. S. Atomic Energy Commission.
[1] S. J. Bame, Phys. Rev. (to be published) and private communication.
[2] A. Hemmendinger and H. V. Argo, Phys. Rev. **98**, 70 (1955).
[3] Jarmie, Allen, and Leland, Bull. Am. Phys. Soc. Ser. II, **1**, 388 (1956), and following abstract.
[4] A. Hemmendinger, Bull. Am. Phys. Soc. Ser. II, **1**, 96 (1956), and private communication.
[5] D. M. Holm and H. V. Argo, Phys. Rev. **101**, 1772 (1956).

E13. $T(t,\alpha)n,n$ Reaction.* Robert C. Allen, Nelson Jarmie, and Ronald E. Brown, *Los Alamos Scientific Laboratory.*—Additional results from the study of the reaction $T(t,\alpha)n,n$ previously described[1] have been found. The tritons, accelerated by an electrostatic generator, bombard gaseous tritium and the alpha particles are observed with a 16-inch double-focusing magnetic spectrometer. At a laboratory angle of 30°, the alpha-particle spectra and excitation function have been determined for incident triton energies of 0.95 to 2.1 Mev. The alpha-particle spectra have also been measured at larger angles. In all cases the effect of the formation and breakup of He^5 is observed. Structure at the high end of the alpha spectra indicates a correlation between the outgoing neutrons and becomes relatively more predominant at larger angles. Measurements of the reaction $He^3(t,\alpha)n,p$ are planned for the future.

* Work performed under the auspices of the U. S. Atomic Energy Commission.
[1] Jarmie, Allen, and Leland, Bull. Am. Phys. Soc. Ser. II, **1**, 388 (1956).

Thursday Afternoon at 1:30

Hellems 111 E

(L. R. Weber presiding)

General Physics

F1. Ionized Strata in the *D* and *E* Regions. E. L. Kilpatrick, *National Bureau of Standards.*—Vertical incidence soundings of the D and E regions at Washington, D. C., throughout 1953 are described. The pulsed exploring signal transmitted at 15-minute intervals swept the frequency range from 50 to 1100 kc/sec during each transmission. The

lowest reflecting stratum was recorded intermittently at heights from 65 to 75 km on winter days only, and then at frequencies less than 500 kc. Median height and critical frequency of the lowest recorded day time stratum increased from winter to summer as normal E descended. Night-time strata occurred predominantly within the height range from 90 to 110 km with a winter-to-summer increase of approximately 5 km in median value. A detailed study of a short period in winter and in summer suggests existence of three principal strata in the combined D and E region which form and coalesce diurnally.

F2. Fading Origin Experiment for Radio Waves Reflected from the Ionosphere. T. N. GAUTIER, R. S. LAWRENCE, W. F. UTLAUT, AND B. WIEDER, *National Bureau of Standards, Boulder.*—The fading of radio wave pulses transmitted via one-hop reflection from the ionosphere between a transmitter and a receiver located 6 km apart has been correlated with the fading of pulses at the same radio-frequency transmitted by vertical incidence reflection between a second transmitter and receiver located at the midpoint of the 6-km path. If scattering is introduced mainly at or near the level of reflection the diffraction patterns around the receivers in the waves of their respective transmitters will be nearly identical, and the fading will be well correlated. Lack of correlation strongly implies that significant scattering occurs well below the level of reflection. Analysis of a number of records made at frequencies between 2.5 and 6 Mc/sec shows that correlation is usually good for E-region echoes, but poor for F-region echoes. A variation of the experiment, involving two paths which intersect at a level that can be changed by moving one of the receivers, fixes the height at which scattering takes place under favorable circumstances.

F3. Radio Studies of Atmospheric Turbulence on Line-Of-Sight Paths. J. W. HERBSTREIT, M. C. THOMPSON, JR., AND K. A. NORTON, *National Bureau of Standards, Boulder.*—Variations in phase-of-arrival of vhf, uhf, and microwave radio signals over line-of-sight propagation paths have been measured using special circuit techniques. The scintillation resulting from atmospheric turbulence has been studied in connection with various surface and airborne measurements of macro- and micrometeorological parameters. Experiments have been conducted on path lengths of from 3 to 60 miles over plains and mountainous terrain and in dry (Southeastern Colorado) and humid (Maui, T. H.) atmospheres. Measurements include variations of phase-of-arrival of a single propagation path and variations in the phase difference between signals propagated over slightly different paths. The data are analyzed with respect to rms fluctuations in phase-of-arrival as a function of time and local meteorological conditions; spectral distribution of these fluctuations; effect of radio-frequency on such phase variations; correlation between phase changes over slightly separate paths as a function of path separation; and correlation between phase behavior and meteorological parameters.

F4. Measurements of Liquid Thermal Diffusivities by an Unsteady State Method.* E. E. KOHNKE AND A. R. SCHMIDT, *Oklahoma State University.*—An oscillating temperature was impressed upon a liquid surface by a flat heating coil carrying a sinusoidal current. The resulting thermal waves were detected at two fixed measuring points below the surface by iron-constantan thermocouples with the sinusoidal component of the thermal emfs being amplified and recorded. Amplitude decrements and phase shifts obtained were used to calculate thermal diffusivities of several liquids. A temperature wave period of 10 minutes and coil and thermocouple separations of approximately 2 millimeters were employed since the small magnitude of liquid thermal diffusivities causes rapid wave attenuation with frequency and distance. Results for several check liquids appear to show a viscosity dependence in that high-viscosity glycerine gives excellent agreement with values reported for steady-state measurements and low-viscosity materials like ethyl alcohol give values several times too small.

* Work supported by Wright Air Development Cneter, Air Research and Development Command, U. S. Air Force.

F5. Fields in Gap-Excited Rectangular Ducts.* J. VAN BLADEL, *University of Wisconsin.*—The electromagnetic field in a rectangular wave guide, cut in two by a plane making an angle θ with the longitudinal axis, is investigated. A voltage applied across the two halves of the guide generates the field structure, which is analyzed for several values of θ, of frequency (between zero and cutoff), and of aspect ratio of the cross section. The problem is of interest for the design of gap-excited particle accelerators, and graphs are presented for the longitudinal and lateral momentum kicks to which particles are subjected when crossing the gap.

* Supported by the U. S. Atomic Energy Commission.

F6. Effect of an Electric Field on the Scintillation Properties of Xenon. D. I. MEYER, *University of Michigan.*—It is well known that xenon gas of high purity is a good scintillator, most of the light being emitted in the ultraviolet region of the spectra.[1,2] In an investigation of some of its properties an electric field was applied across the gas. While the field was still well below the breakdown point it was found that the light output of the scintillator was enhanced. This was accompanied by a great increase in the pulse rise time. This technique might prove useful in the study of certain aspects of gas discharges.

[1] R. A. Nobles, Rev. Sci. Instr. 27, 280 (1956).
[2] Palevsky, Zimmerman, and Larsson; Rev. Sci. Instr. 27, 323 (1956).

F7. Distribution of Lyman-Alpha Radiation on the Sun.* R. C. MERCURE, JR.,† *University of Colorado.*—An Aerobee rocket containing a monochromatic camera with its pass-band centered at the Lyman-α line was flown to a height of 85 miles. During this flight pictures of the solar disk taken in Lyman-α light were obtained. One of these pictures has been published.[1] Four pictures of the sun from this flight have been analyzed using a modified Leeds and Northrup microdensitometer. From these four photographs a composite isophote map of the solar disk in Lyman-α radiation has been constructed. The areas of enhanced Lyman-α radiation correspond to the active areas of the sun when viewed in H-α or Ca II light. The maximum intensity of Lyman-α found was four times the background intensity, and the average intensity of the active areas was about twice the background intensity.

* Supported by the Air Force Cambridge Research Center.
† Now at Ball Brothers Research Corporation.
[1] Mercure, Miller, Rense, and Stuart, J. Geophys. Research 61, 571 (1956).

F8. Optical Birefringence Induced by an Oscillating Plane in Aqueous Milling Yellow Solutions.* GEORGE B. THURSTON AND LOGAN E. HARGROVE, JR., *Oklahoma State University.*—A flow-birefringent fluid has been used to study the relationship between the optical interference pattern induced by an oscillating plane and the properties of the transverse shear wave propagating from its surface. The fluid was placed between crossed plane polarizing plates with the light path, direction normal to the plane, and direction of plane oscillation being mutually perpendicular. The experimental work was

done with planes oscillating at frequencies ranging from 5 to 200 cps in a 1.30% aqueous milling yellow solution. Milling yellow is a commercial dye product of the National Aniline Division of the Allied Chemical and Dye Corporation. Properties of the observed zero-order interference patterns are presented as functions of phase and frequency. It is found that these patterns exhibit wave properties which may be related to the shear wave. Zero-order fringes propagate from the plane with constant velocity. Zero-order fringe spacing exhibits a frequency dependence which is not consistent with that derived for viscous wavelength.

* This work was supported by the Office of Ordnance Research of the U. S. Army.

F9. Spectrum of Turbulence in the Inertial Range.* ROBERT H. KRAICHNAN, *New York University.*—On the basis of a recent theory,[1] there exists at sufficiently high Reynolds numbers an inertial wave-number range of isotropic turbulence in which mean energy-transfer proceeds by cascade. However, direct interaction with the energy-containing range essentially determines the time-autocorrelation functions of the inertial range modes and thereby importantly affects the magnitude of the transfer. A consequence is that Kolmogorov's dimensional considerations, and spectrum form, are not supported. Instead, it is found that the inertial range spectrum has the asymptotic form $E(k)=c(\epsilon v_0)^{1/2}k^{-3/2}$, where $E(k)dk$ is the energy/unit mass in the interval dk, ϵ is the mean rate of energy-transfer/unit mass, v_0 is the rms velocity for the energy-containing region, and c is a universal number fixed by the theory. The autocorrelation function for an inertial mode is asymptotically $(av_0k\tau)^{-1}J_1(2av_0k\tau)$, where τ is difference time and a is a universal number fixed by the theory. These results appear not to conflict with known measurements.

* Supported by the Geophysics Research Directorate, Air Force Cambridge Research Center.

[1] R. H. Kraichnan, Report MH-7, Division of Electromagnetic Research, Institute of Mathematical Sciences, New York University (April, 1957), and Bull. Am. Phys. Soc. Ser. II, 1, 341 (1956).

F10. Response of a Thin Dyke to Oscillating Dipole.* J. P. WESLEY, *University of California Radiation Laboratory.*—A thin dyke of sulfide ore may be geophysically prospected by observing its response to a slowly oscillating magnetic dipole source. To a first approximation the field produced is that of a dyke of infinite conductivity and vanishing thickness for which the solution may, suprisingly, be obtained exactly and in simple closed form as a Green's function. However, to identify the ore and to estimate the size of the deposit, it's necessary to consider a further approximation involving the conductivity and thickness of the dyke. By a type of analytical continuation an approximation is found that agrees both with the exact solution for a dyke of infinite conductivity and vanishing thickness when $\sigma\to\infty$ and the thickness goes to zero and with the exact solution (approximated only for $\omega\sigma$ large and for $\omega\sigma$ small) for an infinite slab of finite conductivity and nonvanishing thickness, the dyke appearing as a infinite slab when both source and observer are near the dyke but far removed from the edge.

* This work was done for Newmont Exploration Limited, Danbury, Connecticut.

F11. Lunar-Solar Perturbations of an Earth Satellite. LEON BLITZER,* *Ramo-Wooldridge Corporation.*—The influence of the sun and moon on the orbit of an earth satellite is investigated via two independent approaches, one employing a perturbation technique and the other based on elementary gyroscopic theory. Both methods yield identical results, and indicate that the principal effect is a precession of the orbit plane about the pole of the ecliptic, analogous to the precession of the equinoxes. Specifically the motion is retrograde, that is, opposite to the direction of motion of the satellite in its orbit, and varies as the cosine of the angle of inclination to the ecliptic. For orbits close to the earth the lunar-solar precessional velocity is only about 10^{-4} that due to the earth's oblateness. While the oblateness effect decreases with orbit size, the lunar-solar precession increases, and in the neighborhood of seven earth radii the two periods are equal. Even at this distance, however, the lunar-solar precession is quite small, having a period in excess of 100 years. Except for very distant orbits the radial perturbations are entirely negligible.

* On leave from Department of Physics, University of Arizona, Tucson, Arizona.

F12. Ionospheric Effects of the Great Solar-Cosmic Ray Event of February 23, 1956. A. H. SHAPLEY AND R. W. KNECHT, *National Bureau of Standards, Colorado.*—A widely reported solar outburst occurred on February 23, 1956, At 0334 UT, a bright flare was observed in progress on the sun (Kodiakanal, India). An unprecedented increase in cosmic-ray intensity began at 0350 to 18 hours for the return to normal. Ionospheric soundings data from both the dark and daylight hemispheres have been examined. Soundings data from 12 stations in the dark hemisphere north of geomagnetic latitude 60° have revealed a large absorption effect whose beginning somewhat lags the start of the solar event and which lasts up to 48 hours. The effect is greatest above 65° and nonexistent below 50°. Between about 51° and 59°, the increase in absorption does not appear in time association with the solar event but rather as an augmentation of the usual daylight absorption during the sunlit hours of the following day (February 23). Except for a moderate effect that was observed at two stations at about 0400, magnetic conditions were generally quiet throughout the period of high absorption until a severe disturbance began 47 hours after the solar event. The apparent mechanism is a steady influx of solar-associated charged particles in the Mev energy range producing an excess of free electrons in the *D*-region or in a subionospheric layer.

THURSDAY EVENING AT 6:30

Chuckwagon Dinner on Flagstaff Mountain

FRIDAY MORNING AT 9:00

Music Auditorium

(J. R. ZACHARIAS presiding)

Invited Papers on Atomic Clocks and Microwave Spectroscopy

G1. Some Introductory Remarks. J. R. ZACHARIAS, *M.I.T.* (10 min.)

G2. Performance and Application of a Caesium Resonator Standard. L. ESSEN, *National Physical Laboratory, Teddington, England.* (30 min.)

G3. Status of Atomic Frequency Control. F. H. REDER, *Signal Corps Engineering Laboratory, Fort Monmouth.* (30 min.)

G4. Collision Narrowing. R. H. DICKE, *Princeton University.* (30 min.)

G5. Optical Monitoring of Free Atom Orientation. H. G. DEHMELT, *University of Washington.* (30 min.)

FRIDAY MORNING AT 9:30

Memorial Center, Forum

(L. MARTON presiding)

Neutron and Electron Physics

H1. Prompt Neutron Emission from Spontaneous Fission Modes of Cf^{252}.* STANLEY L. WHETSTONE, JR., WILLIAM E. STEIN, AND H. L. SMITH, *Los Alamos Scientific Laboratory.*—The number of prompt neutrons emitted and the velocities of the two fission fragments have been measured for individual spontaneous fissions of Cf^{252}. From the measured fragment velocities, the mass numbers, and kinetic energies of each fragment are determined. The double-velocity method not only can provide the resolution desired in the determination of these quantities, but also permits a good estimate to be made of the resolution actually attained. The fragment velocities are obtained from time-of-flight measurements, recorded by two time-to-pulse-height converters followed by two 199-channel pulse-height analyzers. The number of neutrons captured in a large cadmium-loaded liquid scintillator during a 50-μsec time interval following a recorded fission event is counted by a fast scaler. The two velocities, the number of neutrons, and the number of pulses occurring in a delayed, background-sampling interval are automatically printed on a paper tape. The data is then processed by an IBM-704. Preliminary data, including the variation of the average number of prompt neutrons with the total kinetic energy and with the mass ratio of the fragments will be presented.

* This work was done under the auspices of the U. S. Atomic Energy Commission.

H2. Anisotropy of Fission Fragments from the Fast Neutron Bombardment of Pu^{239}.* J. E. SIMMONS, R. L. HENKEL, AND J. E. BROLLEY, *University of California, Los Alamos Scientific Laboratory.*—A thin Pu^{239} foil has been irradiated with neutrons of energies in the range 0.60 to 22 Mev. Using a collimated double ionization chamber, the intensity of fission fragments was measured at zero and ninety degrees to the incident beam. Light and heavy fragments were not distinguished. The measured zero to ninety degree ratios are listed below as functions of the incident neutron energy E_N, in Mev.

E_N	0.62±0.2,	1.5 ±0.13,	2.9 ±0.2,	5.0 ±0.12
0/90	1.13±0.12,	1.23±0.2,	1.26±0.12,	1.30±0.12
E_N	7.1 ±0.3,	8.7 ±0.3,	18.6 ±0.35,	21.5 ±0.5
0/90	1.29±0.10,	1.14±0.11,	1.19±0.2,	1.04±0.10

These data will be compared to the prediction of A. Bohr[1] concerning Pu^{239}. The expected large anisotropies have not been observed.

* Work performed under the auspices of the U. S. Atomic Energy Commission.

[1] A. Bohr, *Proceedings of the International Conference on the Peaceful Uses of Atomic Energy, Geneva 1955* (United Nations, New York, 1951), Vol. 2, p. 151.

H3. Elastic Scattering of Fast Neutrons from Oxygen and Nitrogen. IRA L. MORGAN, J. T. PRUD'HOMME, NORMAN A. BOSTROM, AND ABDUL R. SATTAR, *Texas Nuclear Corporation.**—Fast neutrons produced from the reactions $D(d,n)He^3$, $N^{14}(d,n)O^{15}$, and $T(d,n)He^4$ have been used to study the angular distribution of elastically scattered neutrons from oxygen and nitrogen. Differential elastic scattering curves for oxygen and nitrogen have been obtained at E_n=3.50, 4.03, 4.30, 4.50, 4.87, 5.15, 7.15, 14.95, and 15.87 Mev. A ring geometry was employed which provided measurements in the range of 23° to 150° in increments of 10°. In general, two types of detectors were used, the scintillating plastic spheres[1,2] and ZnS[3] disks. The size and number of spheres were selected to provide maximum neutron efficiency, and maximum gamma-ray discrimination. Thin ZnS disks were used where gamma-beta backgrounds became large.

* This research was supported in whole or in part by the U. S. Air Force Under Contract AF 33(616)-3790, monitored by Aeronautical Research Laboratory, Wright-Patterson Air Force Base, Ohio.

[1] M. Walt and J. R. Beyster, Phys. Rev. 98, 677 (1955).
[2] Taylor, Lonsjo, and Bonner, Phys. Rev. 100, 174 (1955).
[3] W. Rhein, Bull. Am Phys. Soc. 30, 26 (1955).

H4. Inelastic Scattering of Fast Neutrons from O, N, and Fe. J. T. PRUD'HOMME, ABDUL R. SATTAR, NORMAN A. BOSTROM, AND IRA L. MORGAN, *Texas Nuclear Corporation.**—A ring-type geometry has been employed to observe the gamma rays due to inelastic scattering of fast neutrons in O, N, and Fe. At E_n=4.85 Mev the observed gamma-ray spectrum from nitrogen shows transitions corresponding to E_γ=2.31 Mev and 1.60 Mev. An excitation curve for the production of the 2.31-Mev and 1.6-Mev gamma rays has been obtained in the neutron energy region of 3.5 Mev to 5.0 Mev. The cross section for gamma-ray production compares favorably with previous work.[1] The gamma-ray spectrum obtained from the

interaction of 14.95-Mev neutrons in N is quite complex. Gamma-ray energies of 7.0 Mev, 4.8 Mev, and 2.3 Mev were observed. Gamma-ray production due to the interaction of 14.95-Mev neutrons in oxygen presented a strong 6.1-Mev transition, plus 2.5-Mev and 3.5-Mev gamma rays which are presumably due to cascade.

* This research was supported in whole or in part by the U. S. Air Force under Contract AF 33(616)-3817, monitored by Aeronautical Research Laboratory, Wright-Patterson Air Force Base, Ohio.
[1] R. B. Day, Phys. Rev. **102**, 767 (1956).

H5. Studies of Gamma Rays from Inelastic Neutron Scattering.* D. A. Lind, *University of Colorado*, R. B. Day, and R. M. Kloepper, *University of California, Los Alamos Scientific Laboratory*.—Gamma rays excited by neutron bombardment of Na, K, and I have been studied using a ring geometry by methods previously described.[1] A sodium ring bombarded by monoenergetic neutrons ranging from 0.5- to 3.2-Mev emitted gamma rays of 0.44, 1.60, 2.05, 2.34, and 2.70 Mev corresponding to levels at 0.44, 2.05, 2.34, and 2.70 Mev. In potassium gamma rays of 2.52, 2.81, 3.05, and 3.59 Mev from levels of the same energies were observed. A careful study of I^{127} showed gamma-ray lines at 0.21, 0.37, 0.42, 0.60, 0.62, 0.74, 1.02, 1.22, and 1.38 Mev. In Pb^{206} a new line at 1.85 Mev was found. Cross sections and excitation functions will be presented.

* Work performed under the auspices of the U. S. Atomic Energy Commission.
[1] Day, Johnsrud, and Lind, Bull. Am. Phys. Soc. Ser. II, **1**, 56 (1956).

H6. $B^{11}(\alpha,n)N^{14}$ Reaction.* E. Haddad,† J. E. Perry, Jr., and R. K. Smith, *University of California, Los Alamos Scientific Laboratory*.—The neutron spectra resulting from the bombardment of thin boron targets, enriched to 99% in B^{11}, with He^+ ions from the large Los Alamos electrostatic accelerator have been measured by a time-of-flight method.[1] The absolute zero-degree differential cross sections have been obtained for the $B^{11}(\alpha,n)N^{14}$ ground state, first excited state, and second excited state transitions for alpha energies from 2 Mev to 7.25 Mev. Angular distributions of the neutrons associated with the ground state and first excited state of N^{14} have also been obtained for alpha energies up to 5.75 Mev. Resonances in the neutron yield corresponding to excited states of N^{15} agree with those previously reported[2] for the alpha-energy range of 2 Mev to 5 Mev.

* Work performed under the auspices of the U. S. Atomic Energy Commission.
† Doctoral candidate from the University of Utah, Salt Lake City, Utah.
[1] L. Cranberg and J. S. Levin, Phys. Rev. **103**, 343 (1956).
[2] Bonner, Kraus, Marion, and Schiffer, Phys. Rev. **102**, 1348 (1956).

H7. Identification of I^{138} as a Delayed Neutron Precursor.* G. J. Perlow and A. F. Stehney, *Argonne National Laboratory*.—Following previous work[1] in which 15.5-sec Br^{85} was found to be a delayed neutron precursor, a search was made for other halogen precursors which may have escaped detection in experiments without chemical separation. Sources were prepared from solutions of fissionable material irradiated in the thermal column of CP-5. A gas flow system was used in which suitable chemistry separated iodine or bromine fission products which were subsequently absorbed by bubbling the gas through CCl_4. After the gas flow was stopped, the decay of the neutron activity in the CCl_4 was observed by means of a BF_3 long counter. The experimental technique differed from that used previously by us chiefly in having smaller solution volumes and less decay of activity in transit between the reactor and the counter. The iodine sample obtained showed the expected I^{137} activity for which a half-life of 24 seconds was obtained. In addition a prominent 6-second group was observed. This is attributed to I^{138} an odd-odd precursor analogous to Br^{86}. Among the bromine fission products, a neutron activity of 4 seconds half-life was found as expected by previous work.[2]

* Work performed under the auspices of the U. S. Atomic Energy Commission.
[1] G. J. Perlow and A. F. Stehney, Bull. Am. Phys. Soc. Ser. II, **2**, 16 (1957).
[2] N. Sugarman, J. Chem. Phys. **15**, 544 (1947).

H8. Measurement of Monoenergetic Neutron Fluxes.* S. J. Bame, Jr., Eugene Haddad, J. E. Perry, Jr., and R. K. Smith, *Los Alamos Scientific Laboratory*.—The $D(d,n)He^3$ and $T(d,n)He^4$ reactions are often used as sources of high-energy neutrons to measure neutron-induced reaction cross sections. The neutron flux has often been determined with a counter telescope,[1] consisting of a polyethylene radiator, followed by two proportional counters, an exit aperture, and a scintillation counter. The threefold coincidence operation of such a telescope is cumbersome, so an evacuated counter system without proportional counters has been tested. Protons from the radiator proceed through an exit aperture into a CsI(Tl) scintillation counter. The pulse-height spectrum caused by a monoenergetic source of neutrons contains a background of many small pulses with a well-separated peak at high pulse heights. With the radiator removed, the spectrum contains the same background of small pulses without the peak. The difference yields the number of protons scattered from the radiator into the counter, from which the neutron flux can be computed, using the calculated efficiency[1] of the system. This technique has been tested successfully at neutron energies of 4, 9, 14, and 17 Mev.

* Work performed under the auspices of the U. S. Atomic Energy Commission.
[1] Bame, Haddad, Perry, and Smith (to be published). See also C. H. Johnson and C. C. Trail, Rev. Sci. Instr. **27**, 468 (1956).

H9. Gamma Rays from the Interaction of 14-Mev Neutrons Using Time-of-Flight Techniques.* C. D. Schrader, J. Benveniste, and J. H. Zenger, *University of California, Livermore*.—Energy spectra of gamma rays resulting from the bombardment of various elements by pulsed 14-Mev neutrons have been obtained. Ring scatterers of Be, C, Al, Fe, Cu, Ag, Cd, Sn, and Pb were placed such that the gammas were observed at 90 degrees to the incident neutron beam. Background neutrons were eliminated by gating a 256-channel pulse-height analyzer by pulses which had passed through a time-to-height converter and a differential discriminator. The discriminator selected from the entire time distribution of pulses reaching the detector only those which arrived at flight times corresponding to those of gamma rays. In general, but with several exceptions, the spectra show some structure below 2 Mev with a continuum above 2 Mev. It is interesting to note that lines observed in lead at 0.80, 1.43, 1.73 Mev and at 0.57 and 0.88 Mev may all be identified with transitions from excited states of Pb^{206} and Pb^{207}, respectively, suggesting that the predominant contribution of gamma rays arises from $(n,2n)$ reactions. Also, a line in the beryllium spectrum at 0.47 Mev has been attributed to the $Be^9(n,t)Li^{7*}$ reaction.

* Work performed under the auspices of the U. S. Atomic Energy Commission.

H10. Inelastic Single Scattering of Medium Energy Electrons. L. Marton, J. A. Simpson, J. A. Suddeth, and M. D. Wagner, *National Bureau of Standards*.—We have reported earlier on experiments indicating that the number of inelastically scattered electrons in the single scattering range may vary with the crystal structure of a scattering specimen. These experiments have been repeated in the medium energy range (~20 kev). To minimize the effect of thickness, we always prepared several specimens having the same thickness but different crystalline structure. This was achieved by

simultaneous evaporation of the same metal onto heated substrates where the temperatures of the substrates were different. Partial or complete orientation of the metal layers was achieved by partial or complete epitaxy. New measurements indicate that there indeed exists a certain degree of correlation between crystallinity of the specimen and the number of inelastically scattered electrons. While a certain number of these measurements defy complete reproducibility, everything happens as if the electrons were, to a good extent, inelastically scattered at grain boundaries, since the ratio of inelastic to elastic is higher for polycrystalline specimens than for single crystal ones.

H11. 50-kev Bremsstrahlung Measurements.* J. W. MOTZ AND R. C. PLACIOUS, *National Bureau of Standards.*—The bremsstrahlung cross sections (differential with respect to photon energy and emission angle θ) for 50-kev electrons ($\beta \approx 0.41$) incident on a 10 $\mu g/cm^2$ gold and a 17 $\mu g/cm^2$ aluminum target have been determined from measurements made with a scintillation spectrometer at angles ranging from 10 to 140 degrees. The results show that at the peak intensity angle of approximately 45 degrees, the experimental cross sections agree within 20% over most of the spectrum with the Sommerfeld cross sections[1] multiplied by the relativistic correction factor $(1-\beta\cos\theta)^{-3}$. At the extreme angles, deviations from the theoretical results increase up to about 50%. The experimental values (10% accuracy) for the Heitler parameter[2] $\phi_{rad}/\bar{\phi}$ are 6.6 and 5.4 for gold and aluminum, respectively, compared to the corresponding theoretical values (including the above relativistic correction factor) of 6.9 and 6.8.

* Work supported by the U. S. Atomic Energy Commission.
[1] The cross sections used for this comparison were calculated by P. Kirkpatrick and L. Wiedmann, Phys. Rev. 67, 321 (1945).
[2] W. Heitler, *The Quantum Theory of Radiation* (Oxford University Press, New York, 1954), third edition, p. 251.

H12. A Measurement of the Electron-Positron Multiple Scattering Difference in Gold. CECIL G. DAVIS, JR.,* AND KENNETH R. MACKENZIE, *University of California at Los Angeles.*—The scattering of electrons and positrons from nuclei is influenced by a spin-orbit interaction in such a way that the electron is deflected through a greater angle than the positron. When this effect is included in the multiple scattering theories, the mean square scattering angle for the positrons is 2 to 6% smaller than for the electrons, depending on the particles energies, the atomic weight, and thickness of the scattering foil. This spin-orbit difference is measurably large for relativistic particles (approximately 1-Mev electrons) and heavy Z elements. To test this effect the multiple scattering distributions for 1.16-Mev electrons and positrons were measured in a 2.03 mg/cm^2 gold foil, with an accuracy between 1 and 2%. This measurement required the construction of a "double magnetic sector" source spectrometer, to be used either with pile sources for the electrons, or cyclotron produced sources for the positrons.

* Now at the Los Alamos Scientific Laboratory, Los Alamos, New Mexico.

H13. K X-Ray Absorption Edges of Zinc. H. P. HANSON, *University of Texas* AND F. A. COTTON, *M.I.T.*—The K x-ray absorption edges of Zn in a variety of chemical compounds have been measured with high resolution. The completed $3d$ shell eliminates some of the complexities found in the edge structures of corresponding compounds of the transition elements. This results in edges that are predominantly determined by the permitted $1s-np$ transitions even in compounds where homopolar bonding must be considered. The main peak in the $Zn(NH_3)_4^{++}$ complex is split in a manner similar to $Cu(NH_3)_4^{++}$ which has been accounted for in terms of symmetry considerations. The edges in the crystallographically similar compounds, ZnO and ZnS, show fundamental differences which will be discussed.

FRIDAY AFTERNOON AT 2:00

Memorial Center, Forum

(B. E. COHN presiding)

Invited Papers on Cosmic Rays

I1. High-Energy Particle Detection in Cosmic-Ray Studies. G. T. REYNOLDS, *Princeton University.* (30 min.)

I2. Identification of High-Energy Secondary Particles in Penetrating Showers. W. B. FRETTER, *University of California, Berkeley.* (30 min.)

I3. Nature and Origin of Primary Cosmic Radiation. E. P. NEY, *University of Minnesota.* (30 min.)

I4. Investigation of Solar Effects on Cosmic Rays with Earth Satellites. S. F. SINGER, *University of Maryland.* (30 min.)

FRIDAY AFTERNOON AT 1:30

Physics 104

(G. GAMOW presiding)

Theory

Invited Paper

J1. Mu-Mesic Molecular Ion Formation and Other Aspects of Nuclear Fusion Catalysis. D. JUDD, *University of California, Berkeley.* (30 min.)

Contributed Papers

J2. Phenomenological Theory of Magnetic Anisotropy. EARL CALLEN, *National Security Agency*, JULIUS L. JACKSON, *National Bureau of Standards*, AND HERBERT B. CALLEN,* *University of Pennsylvania*.—In addition to its interaction with an external field and with an internal molecular field, we assume that each dipole in a cubic magnetic crystal such as iron has an energy of interaction with its environment which can be expressed as $K_1(\alpha_1^2\alpha_2^2+\alpha_2^2\alpha_3^2+\alpha_3^2\alpha_1^2)$ plus $K_2\alpha_1^2\alpha_2^2\alpha_3^2$, where K_1 and K_2 are temperature-independent physical constants of the material, and the α_i are the direction cosines of the dipole with respect to the cubic crystal axes. Using these terms for the energy of an individual dipole, and assuming a Boltzmann distribution, we obtain an equation for the magnetization, the leading term of which is the isotropic Langevin function, and we calculate the expectation value of the energy. This is carried out to first order in the anisotropy coefficients. The temperature-dependent anisotropy constants are then extracted. Employing the accepted values of K_1 and K_2 at $T=0°$K, and of the Curie temperature, we find a very good agreement with the experimental curve for K_1 as a function of temperature, for iron.

* Supported by the Office of Naval Research.

J3. Adaptation of Richards' Transport Approximation to Multi-Group One-Dimensional Reactor Computations. RICHARD L. MOORE, *Planning Research Corporation*.—Richards'[1] transport approximation

$$(\lambda^2\nabla^2(1-2\omega/3)\rho-(1-\omega)\rho=(\lambda^2\nabla^2-1)\rho_d +2\sum_n^\infty(\lambda^2\nabla^2)^n(\omega\rho)/(4n^2-1))$$

is adapted to a multi-region spherical reactor. The uncollided flux (ρ_d) is approximated by sums of exponentials which form the inhomogeneous terms in a multi-group system of differential equations. Boundary conditions and other transformations are presented. The solution is obtained by matrix methods and polynomial approximations to integrals. This method is expected to compute the flux in a reactor much more accurately than the diffusion equation. Although it will require more operations than the matrix solution[2] of the diffusion equation, a four-region, ten-group computation will be an order of magnitude faster than numerical approximations which require many mesh points for comparable or better accuracy. The estimated number of multiplicative operations for a complete criticality computation is 3×10^5 to 3×10^6. The adaptation for heat transfer computations is also promising from accuracy and speed considerations.

[1] Paul I. Richards, Phys. Rev. **100**, 517 (1955).
[2] P. Schmid, *Proceedings of the International Conference on Peaceful Use of Atomic Energy, Geneva, 1955* (United Nations, New York, 1956), Vol. 5, p. 444.

J4. Angular and Energy Distributions of Plane Monodirectional γ Radiation after Transmission through Pb Slabs.* JOHN HUBBELL, EVANS HAYWARD, AND WALTER F. TITUS, *National Bureau of Standards*.—Moments-method calculations[1] predict a peak at ~1 Mev in deep-penetration γ-ray spectra in lead, rather than at the minimum attenuation energy $E(\mu_{\min})$ of ~3 Mev. To investigate this and other features of γ-ray penetration for source energies $>E(\mu_{\min})$, 8- and 10-Mev bremsstrahlung from the NBS betatron were used as broad-beam sources normally incident on 4- and 6-inch slabs of Pb. Transmission spectra were measured at 0° to 70° from the beam direction using a collimated NaI(Tl) spectrometer. Integration over angle yielded a 0.511-Mev annihilation radiation peak and a ~1.3-Mev diffusion peak. A theoretical comparison was obtained by folding into the incident spectra results of moments-method calculations for monoergic sources. The theoretical annihilation component was added. According to these calculations the diffusion peak is at ~1.1 Mev. Slab rather than infinite geometry and omission of bremsstrahlung from the calculation account for differences.

* Supported by the U. S. Atomic Energy Commission and the Office of Naval Research.
[1] L. V. Spencer and U. Fano, Research Natl. Bur. Standards **46**, 446 (1951); H. Goldstein and E. Wilkins, NYO-3075, NDA Rept. 15C-41 (1954).

J5. Optical Model Analysis of K^+ Meson Scattering.* G. IGO, D. G. RAVENHALL, AND J. J. TIEMANN,† *Stanford University*, J. LANNUTTI, G. GOLDHABER, AND S. GOLDHABER, *University of California, Berkeley*, AND R. M. THALER, *Los Alamos Scientific Laboratory*.—The scattering of K^+ mesons of energies near 150 Mev and in the internal 40 to 100 Mev has been analyzed in terms of a complex potential, $(V+iW)/[1+\exp[(r-r_0)/d]]$. The quantities r_0 and d were taken to be 1.07 A[1] and 0.47 fermi respectively. An exact phase shift analysis has been made for each element in the emulsion and at several energies in order to arrive at a suitable energy average for comparison with events detected in emulsions. Utilizing a repulsive potential, an adequate fit to the differential cross section for elastic scattering, the total cross section, and the inelastic cross section was obtained with V and W equal to 25 and -10.6 Mev, respectively. At the lower energies, the best fit was obtained with V and W equal to 20 and -4.9 Mev. When V is made attractive, the fits to the differential cross section for elastic scattering are less good particularly in the region of the interference minimum. The improvement over previous calculations of this process lies in its inclusion of W in the elastic cross section.

* This research was supported jointly by the U. S. Atomic Energy Commission and the U. S. Air Force through the Office of Scientific Research, Air Research and Development Command.
† I.B.M. Fellow in Applied Physics 1956–1957.

J6. Relativistic Self-Consistent Solutions for Heavy Atoms. STANLEY COHEN. *The RAND Corporation and University of California, Berkeley*.*—Relativistic self-consistent wave functions without exchange have been obtained for several atoms of large atomic number. In this calculation each of the electrons in the atom is assumed to satisfy the single-particle Dirac equation in the combined Coulombic fields from the nucleus and the other electrons of the atom. An iterative procedure similar to that of Hartree was used to obtain self-consistent results accurate to at least 1 part in 10^4. The results for the neutral atoms Pt, W, Hg, and U will be presented. These calculations were performed on the RAND Corporation IBM-704 computer.

* This work was performed under the auspices of the U. S. Atomic Energy Commission.

J7. K-Meson Contribution to Forces between Baryons. DON B. LICHTENBERG AND MARC ROSS, *Indiana University*.—In connection with work on the pion contribution to hyperon nucleon forces (in press), we have investigated the role of forces due to K-particle exchange. The presence of hyperon nucleon coupling due to K particles is known, but little is known of the associated coupling constants. We have calculated potentials associated with second- and fourth-order K exchange and the fourth-order K and π exchange, as they depend on K parity and the coupling constants to the different hyperons. The K and π exchange potential is about as long ranged as the second-order K potential but the coefficient is small unless one considers pion emission by hyperons in addition to pion nucleon coupling. For comparison with experiment some simplifying assumption is necessary to reduce the number of coupling constants. Then the principal

unknown constant is roughly fixed by hyperfragment binding data. Two viewpoints may be taken. Considering the K to be pseudoscalar, for example, the PV K particle coupling constant, f_K^2, may be somewhat larger than the well-known pion-nucleon constant, f^2. If so, hyperon nucleon forces could be due to K particles as first discussed by Wentzel, and the pion-hyperon coupling constants could be small. If, on the other hand, pion-hyperon coupling constants are comparable to f^2 then f_K^2 could be smaller than f^2. In this case the K-particle forces would merely be corrections to pion forces. Comparison of these possibilities with the simple pion exchange forces as regards hyperon nucleon binding and scattering will be made.

J8. Decay of Spin 3/2 Muon. LAURIE M. BROWN,* *Northwestern University* AND V. L. TELEGDI, *University of Chicago.*—Although all available evidence on electromagnetic properties of the muon is in strong disagreement with the spin $\frac{3}{2}$ theory of Fierz and Pauli, the theory of higher spin particles in the presence of the electromagnetic field can be questioned. The theory of the muon beta decay, on the other hand, gives an excellent fit[1] to the electron energy distribution with the parameter $\rho'=0.25$. The electron spectrum of decay of a *polarized* muon gives additional constraints on the theory which may make it possible to rule out spin $\frac{3}{2}$. Preliminary results for the decay $\mu\to e+\nu+\bar{\nu}$ with two-component neutrinos[2] gives a spectrum proportional to $(1+\xi\varpi\cdot\mathbf{p}_e)$ where $\xi=2\,\mathrm{Re}fvf_A^*(|f_V|^2+|f_A|^2)^{-1}$. The factor I_0 contains terms in $(\hat{\varpi}\cdot\hat{\mathbf{p}}_e)^2$ contrary to experiment and has $\rho'=0$. The case of a general parity nonconserving interaction will be discussed.

* Work supported in part by the National Science Foundation.
[1] R. E. Behrends and C. Fronsdal, Phys. Rev. 106, 345 (1957).
[2] Abdus Salam, Nuovo cimento 5, 299 (1957); L. D. Landau, Nuclear Phys. 3, 127 (1957); T. D. Lee and C. N. Yang, Phys. Rev. 105, 1671 (1957).

J9. On Maximum Parity Nonconservation. WERNER B. TEUTSCH, *Tufts University and General Dynamics Corporation.*—The experiments suggested by Lee and Yang[1] have shown that parity is not conserved in the weak interactions involving neutrinos, and in fact that the parity nonconservation attains a maximum. The symmetry implied by maximum parity nonconservation may be illustrated with a simple hypothetical experiment. Consider a particle A with spin j which decays into a slightly lighter particle B with zero spin and a massless particle C with spin j. Polarize an ensemble of A particles in the x direction so that $\langle J_x\rangle_i=j$, say. Let the C particles emitted in the z direction impinge upon an absorber consisting of B particles, and measure $\langle J_x\rangle_f$ of the A particles which are thus produced. Analysis of this experiment shows that $\langle J_x\rangle_f=0$, when $j\neq\frac{1}{2}$, and $\langle J_x\rangle_f=\langle J_x\rangle_i$, when $j=\frac{1}{2}$. The requirement that $\langle J_x\rangle_i=0$, even in the case of $j=\frac{1}{2}$, is exactly the requirement of maximum parity nonconservation. The restriction thus imposed is slightly weaker than that imposed by the two-component neutrino theory.

[1] T. D. Lee and C. N. Yang, Phys. Rev. 104, 254 (1956); Wu, Ambler, Hayward, Hoppes, and Hudson, Phys. Rev. 105, 1413 (1957); Garvin, Lederman, and Weinreich, Phys. Rev. 105, 1415 (1957); J. I. Friedman and V. L. Telegdi, Phys. Rev. 105, 1681 (1957).

J10. Compton Cross Section for Circular Photon Polarization and Arbitrary Electron Spin Orientation.* L. H. SCHICK AND S. C. MILLER, JR., *University of Colorado.*—The nonconservation of parity has led to experiments involving the detection of electron spin orientation and to experiments involving the detection of circularly polarized photons by the Compton process. Compton scattering has been previously considered either for cases independent of the initial or final electron spin orientation or for cases independent of the polarization of the scattered photon.[1-3] In view of these recent developments we have calculated the Compton cross sections for circular polarization of the incident and the scattered photon and arbitrary initial and final spin orientation of the electron. The results of these calculations will be presented.

* Work supported in part by the U. S. Atomic Energy Commission.
[1] W. Franz, Ann. Physik 33, 698 (1938).
[2] A. Wightman, Phys. Rev. 74, 1813 (1948).
[3] U. Fano, J. Opt. Soc. Am. 39, 859 (1949).

J11. Semiclassical Limit for Excitation of Rotational Motion by Scattering. DAVID M. CHASE, *Technical Research Group.*—Scattering of particles by interaction with a rotating axially symmetric potential presented by a target having a rotational spectrum, as in excitation of rotational motion in deformed nuclei by neutron scattering, constitutes a problem previously treated in various ways. The adiabatic approximation regards the target moment of inertia as infinite and yields the collision matrix simply in terms of that for elastic scattering by a static well. A semiclassical approximation further regards the target angular momentum $\mathbf{I}$ as large compared with that transferred in the collision. In this treatment the target rotates classically about $\mathbf{I}$. The time-modulated elastic scattering amplitude is Fourier-analyzed, and the components are associated with rotational excitations as in the Raman effect. Cross sections averaged over the azimuth of $\mathbf{I}$ are directly comparable with expressions from the adiabatic approximation. Exact correspondence is found in the envisaged limit by virtue of the limiting form for vector addition coefficients:

$$\lim_{L_1\to\infty}(L_1\ell_2M_1m_2|\,L_1+c,M_1+m_2)=D^{\ell_2}{}_{m_2m_2}(\cos^{-1}(M_1/L_1),0,0).$$

This equality can be proved directly.

J12. Threshold Law for Reactions Leading to One Neutral and Two Charged Products.* ERNEST P. GRAY, ROBERT W. HART, AND WILLIAM H. GUIER, *The Johns Hopkins University.*—The energy dependence near threshold of cross sections for reactions leading to the escape of one neutral and two charged particles is determined. The method is an extension of one developed previously for uncharged particles,[1] and utilizes only general properties of solutions of the time-independent three-particle Schroedinger equation valid outside a reaction zone of finite extent. Electron detachment from H^- by charged particle bombardment, and nuclear reactions of the type (n,np) are considered as examples.

* This work supported by the Bureau of Ordnance, Department of the Navy, under NOrd 7386.
[1] W. H. Guier and R. W. Hart, Phys. Rev. 106, 296 (1957).

J13. Gartenhaus-Schwartz Transformation.* MURRAY PESHKIN, *Argonne National Laboratory, and Northwestern University.*—Gartenhaus and Schwartz[1] have found a transformation which removes the spurious motion of the center of mass by projecting out the translationally invariant part of the wave function of a many-particle system. The same transformation can be obtained in an entirely transparent way which has the further advantage that it avoids the use of singular operators. Let $\varphi(r_1,\cdots r_N)$ be the model wave function for N particles of equal mass. Define $s_1,\cdots s_N$ by the orthogonal transformation $r_k=\Sigma a_{kl}s_l$, with $a_{kl}=1/\sqrt{N}\,\chi(s_1\cdots s_N)\equiv\varphi(r_1\cdots r_N)$. $\psi_\epsilon(r_1\cdots r_N)\equiv\chi(\epsilon s_1,s_2\cdots s_N)\equiv\varphi(r_1'\cdots r_N')$, where $r_k'=r_k-(1-\epsilon)(r_1+\cdots+r_N)/N$. ψ_ϵ has precisely the same internal structure as φ, but in the limit $\epsilon\to0$, ψ_ϵ is independent of s_1, the center-of-mass coordinate. The Gartenhaus-Schwartz transformation now appears as a simple change of the variables of integration when matrix elements are calculated using $\varphi(r_1'\cdots r_N')$ instead of $\psi_\epsilon(r_1\cdots r_N)$. Since the Jacobian for the transformation is $1/\epsilon$, the transformation

rules must be obtained for finite ϵ before the limit is taken. Unequal masses present no difficulty.

* Work performed under the auspices of the U. S. Atomic Energy Commission.

[1] S. Gartenhaus and C. L. Schwartz, Bull. Am. Phys. Soc. Ser. II, 1, 383 (1956), and unpublished manuscript.

J14. Theory of High-Energy Potential Scattering.* D. S. SAXON,† *Institut for Teoretisk Fysik, Copenhagen,* AND L. I. SCHIFF,‡ *École Normale Supérieure, Paris.*—A new formulation for high-energy potential scattering[1] is extended to provide explicit formulas for the scattering theory of the three-dimensional nonseparable Schrödinger equation. An integral equation is derived, for which a single iteration gives the scattering when the potential energy is not too large and is slowly-varying compared to a wavelength. The result agrees with those obtained earlier for small and for large scattering angles,[2] but applies as well to intermediate angles and improves the earlier accuracy. Further iterations can provide greater accuracy as well as an error estimate for the first approximation. A full account has been submitted to *Il Nuovo Cimento.*

* Supported in part by the U. S. Air Force through the European Office, ARDC.

† Guggenheim Fellow; permanent address: University of California, Los Angeles, California.

‡ Guggenheim Fellow, permanent address: Stanford, California.

[1] D. S. Saxon, submitted to *The Physical Review.*

[2] L. I. Schiff, Phys. Rev. **103**, 443 (1956).

J15. Some Extensions of Fermi's Statistical Model. MAURICE NEUMAN, *University of California, Berkeley.**—A completely covariant formulation of Fermi's statistical model has been made. Its connection with the S matrix via a covariant version of the Wigner coordinate-momentum distribution function will be indicated. Spin effects and correlation effects arising from indistinguishability of elementary particles can be included by the method presented.

* This work was performed under the auspices of the U. S. Atomic Energy Commission.

FRIDAY AFTERNOON AT 1:30

Hellems 111 E

(D. G. BURKHARD presiding)

Solid State II

K1. Photoelectric Location of the Valence Band in AgBr. E. A. TAFT, H. R. PHILIPP, AND L. APKER, *General Electric Research Laboratory.*—Thin crystal plates of pure AgBr, kindly furnished for these experiments by Dr. J. W. Mitchell of the University of Bristol, were studied as photoemitters in sealed-off tubes. The photoelectric yield rose rapidly at a threshold photon energy near 6 ev (a behavior not essentially different from the early results of Fleischmann).[1] It reached plateau values of order 0.05 electron/incident photon in the range 8 ev $< h\nu <$ 11 ev. The results are similar in character to those for pure alkali halides[2]; in a parallel manner, they are interpreted here as photoemission from the valence band of AgBr, which thus lies about 6 ev below the vacuum level. The plateau yield 0.05 is reasonable for an electronic energy structure like that of AgBr. We wish to thank Dr. P. D. Johnson for the use of his recording vacuum spectrograph.

[1] R. Fleischmann, Ann. Physik **5**, 73 (1930).

[2] H. R. Philipp and E. A. Taft, J. Phys. Chem. Solids **1**, 119 (1956) and a subsequent paper to be published in 1957.

K2. Transport of Electrons in Intrinsic InSb. H. EHRENREICH, *General Electric Research Laboratory.*—The mobility, thermoelectric power, Hall coefficient, and far-infrared reflectivity are calculated using the polar interaction modified by screening and the p-function admixture in the nonparabolic conduction band of InSb. Both effects are important above 300°K, increasing the mobility above previously calculated values.[1] Agreement with experiment is regained after proper combination of polar and electron-hole scattering. The variational principle used to solve the Boltzmann equation is improved by use of the high-energy asymptotic solution, permitting application to other materials whose band structure is accurately known in only a small region about the band edge, and generalized to account for more than one scattering mechanism. A variational technique is developed for treating transport effects in small magnetic fields and applied to the Hall effect. Finally the Boltzmann equation is used to obtain the optical properties in the far infrared for polar scattering and the correct conduction band structure. The results, valid for photon energies considerably smaller than KT, compare well with experiment.[2]

[1] H. Ehrenreich, J. Phys. Chem. Solids **2**, 131 (1957).

[2] H. Yoshinaga and R. A. Oetjen, Phys. Rev. **101**, 526 (1956).

K3. Effect of Electron-Electron Scattering on the Transport Properties of Semiconductors.—ROBERT W. KEYES, *Westinghouse Research Laboratories.*—Electron-electron collisions cause the electronic distribution function, f, to decay towards f_0^*, a Boltzmann distribution in the electronic center-of-mass system. In order to study the effect of these collisions on the transport properties of various semiconductor models, we have used a relaxation time approximation to introduce this decay into the Boltzmann equation, thus:

$$\frac{\partial f}{\partial t} = -\dot{\mathbf{p}} \cdot \nabla_{\mathbf{p}} f - \frac{f - f_0}{\tau_p} - \frac{f - f_0^*}{\tau_1}. \tag{1}$$

Here τ_p is the ordinary relaxation time, which represents the rate of loss of momentum to the lattice vibrations or other crystal imperfections; τ_1 is a constant which characterizes the strength of the electron-electron scattering. If f_0^* is expanded to first-order terms in the center-of-mass velocity, Eq. (1) can be solved in the usual way. We have worked out the solutions of Eq. (1) for the simple isotropic and cubic multi-valley models in the presence of various combinations of electric and magnetic fields and will present some of the results.

K4. One-Dimensional Impurity Bands. M. LAX AND J. C. PHILLIPS, *Bell Telephone Laboratories.*—The density of states of one-dimensional crystals consisting of δ functions randomly distributed has been calculated on the IBM 650. The chains contained 1000 atoms, and the most probable error in the integrated density of states at various energies was estimated to be at most $\frac{1}{2}\%$. Calculations were performed for various values of the parameter $\epsilon = n/\kappa_0$, where n is the density of atoms and κ_0 the attenuation constant appropriate to the isolated bound state. It was found that for $\epsilon \ll 1$ a pair theory

fits the results fairly well, while for $\epsilon \gg 1$ a virtual crystal approximation is appropriate. Results for intermediate densities, $\epsilon \sim 1$, will also be presented.

K5. Plasma Oscillations in Many-Valley Semiconductors.* LOUIS GOLD,† *Lincoln Laboratory.*—The present paper represents a logical extension of plasma oscillations in isotropic ionized gaseous media to semiconductors such as germanium or silicon. Certain approximations and idealizations imposed in the gaseous plasma are much more realistic in the latter substances. For example, the donor (acceptor) ions certainly do not contribute to the current flow so the current is truly due only to electrons (holes). The theory is founded on a transformation scheme already described[1] which makes possible analysis even for the circumstance of an arbitrarily oriented static magnetic field **B**. A general expression for plasma resonances in a many-valley semiconductor is derived and the oscillation amplitudes characterized in detail for transverse and longitudinal alignments of the electric field **E** relative to **B**. While in general two distinct resonances are possible for each combination of **E** and **B**, as is particularly so for the longitudinal array, the transverse case admits only one. In any case identification of amplitude(s) requires solution of a set of four transcendental equations. The possible observation of such plasma oscillations demands characterization of the amplitudes for diverse orientations of **E** and **B** relative to the crystallographic axes.

* The research reported in this document was supported jointly by the U. S. Army, Navy, and Air Force under contract with the Massachusetts Institute of Technology.
† Staff Member, Lincoln Laboratory, Massachusetts Institute of Technology.
[1] See M.I.T. Physical Electronics Conference Report 1957; Soviet Physics JETP 4, 290 (1957) has letter by R. V. Polovin on substantially the same scheme and appeared in the untranslated issue August, 1956.

K6. Electronic Energy Bands in Lithium.* M. L. GLASSER AND J. CALLAWAY, *University of Miami.*—The orthogonalized plane wave method has been employed for a calculation of electronic energy levels in lithium, using the empirical Seitz potential as published by Rostoker and Kohn.[1] The $1S$ core state was obtained by numerical integration for that potential. The energies of twenty-four different types of states were obtained for four symmetry points in the Brillouin zone: Γ, H, P, and N. The lowest energy level was found to be in good agreement with the value obtained by the cellular method. The states closest to the Fermi surface at symmetry points are of P character. The relation between the energy bands in lithium and those calculated for the other alkali metals will be discussed.

* Supported by the Office of Naval Research.
[1] W. Kohn and N. Rostoker, Phys. Rev. 94, 1111 (1954).

K7. Temperature Dependence of Capture Cross Sections of Indium in Silicon. G. K. WERTHEIM, *Bell Telephone Laboratories.*—The cross sections for a hole and electron capture by indium in silicon have been obtained from measurements of the lifetime of excess carriers made with the pulsed Van de Graaff technique. Detailed measurements have been made on a sample containing 1.4×10^{17} acceptors/cm^3. The statistics of recombination for a system whose lifetime is limited by recombination through the acceptors which control carrier concentrations indicates a high-temperature lifetime limited by electron capture and a low-temperature lifetime limited by hole capture. On the basis of this analysis the cross section for electron-capture by a neutral indium atom is $1.1\times10^{-14}T^{-1}$ cm^3 and that for hole-capture by an ionized atom $1.5\times10^{-9}T^{-3}$ cm^3. (3.7×10^{-17} cm^3 and 1.7×10^{-14} cm^3 at room temperature) The magnitudes and temperature dependences are in reasonable agreement with those expected for neutral and Coulomb attractive sites respectively.[1] These results suggest that lifetimes in heavily doped crystals may be limited by recombination through the chemical donors and acceptors. Measurements on n-type crystals containing indium as an impurity will be reported.

[1] M. Lax (private communication).

K8. "Ring Diode" Technique and Silicon Diode dc Characteristics. H. L. TAYLOR AND W. A. ADCOCK, *Texas Instruments Incorporated.*—A "ring-guarded diode junction" technique, analogous to the guard ring technique with capacitors, has been used for measuring separately the bulk dc characteristics of a p-n junction and the surface characteristics. In this method a ring is electrolytically etched into the surface parallel to the junction to produce a center diode separated from a ring diode by a thin layer of material near the junction. The bulk characteristics of the center diode are observed by maintaining this diode region and the ring diode at the same potential and measuring the current through the center diode. The accuracy of this method is limited by the resistance separating the center and ring diodes and by the sensitivity of the null detector used. The surface effects can also be studied to some extent by this method. Some data on grown silicon junctions will be presented. A real saturation current as predicted by diffusion theory is observed. The calculated saturation current is in good agreement with measured saturation current above room temperature.

K9. Mean Life of Positrons in Alkali Halide Crystals.* LOUIS BROWN, CHARLES HATCHER, AND W. E. MILLETT, *University of Texas.*—The mean life of positrons in LiF, NaCl, KCl, and KI has been measured by using Gerholm's technique.[1] Only a fast component has been observed and the capabilities of the equipment are such as to reveal any long component accounting for more than 1% of the annihilations. The values obtained in units of 10^{-10} sec are LiF 2.3, NaCl 3.2, KCl 3.2, and KI 3.1; the probable error associated with each measurement is 0.3. Measurements were made of the mean lives in Al and Teflon for comparison with the work of other investigators. Good agreement with the values reported by Gerholm was found except that no long component was observed in Al; the effect on which the report of the long component had been based was observed but the same effect was noticed in the four crystals and, to a lesser extent, in the Co^{60} resolution curve.

* Supported in part by the U. S. Air Force Office of Scientific Research of the Air Research and Development Command.
[1] T. R. Gerholm, Arkiv Fysik 10, 523 (1956).

K10. Thermal emf of Several Thermometric Alloys. M. D. BUNCH, ROBERT L. POWELL, AND R. J. CORRUCCINI, *National Bureau of Standards.*—Three different alloys, gold-cobalt, constantan, and "normal" silver have been tested for their usefulness as low temperature thermocouple elements. The thermocouples were calibrated between 4°K and 300°K with their reference temperatures at the normal boiling points of liquid helium, liquid hydrogen, and liquid nitrogen. Some of the wires were also tested for uniformity, homogeneity, and time variation over a period of several months. The alloy system gold plus 2.1 atomic percent cobalt[1] has a relatively high thermal electromotive power *versus* copper at low temperatures (15 μv/°K at 20°K). Several years ago commercial melts of the alloy had variations of up to 7% in the thermal emf. More recent melts vary by approximately ¼%. Constantan with copper is a much less sensitive thermoelement, but is more reproducible. The alloy "normal" silver,[1] silver plus 0.35 atomic percent gold, has a very low absolute thermal emf and is often used as a companion element with gold-cobalt. Commercial copper itself shows considerable variation of the thermal emf at the lowest temperatures.

[1] G. Borelius *et al.*, Leiden Comm. No. 217d (1932).

K11. Field Effect Studies on Silicon Transistors. B. SCHWARTZ AND M. LEVY, *Hughes Aircraft Company* (introduced by R. A. Gudmendsen).—Field effect experiments on silicon have shown results very similar to those found in germanium studies by Many *et al.*[1] The emitter surface of an operating transistor is made one plate of a high-voltage condenser and a high electrostatic field (10^6 v/cm) can be applied between this surface and the field place (i.e., the other plate of the condenser). When this technique is used, changes in α are noticed which follow the relation $\Delta\alpha = -k(\alpha)V$ and which are interpreted as being due to changes in surface recombination velocity. When a dc field voltage is used, α is initially displaced but recovers with time for a constant applied voltage. At least two time constants have been observed, differing by a factor of about 7, and they indicate the possible existence of more than one type of slow surface state. Changes of the same nature as described above have been observed in I_{e0} and agree with the work of E. N. Clarke[2] on field effect and channel growth.

[1] Many, Margoninski, Harnik, and Alexander, Phys. Rev. **101**, 1433–1435 (1956).
[2] E. N. Clarke, Phys. Rev. **99**, 1899–1900 (1955).

K12. Theory of Impurity Photoionization Spectrum of Semiconductors in Magnetic Fields. R. F. WALLIS, *U. S. Naval Research Laboratory*, AND H. J. BOWLDEN,* *Wayne State University* and *U. S. Naval Research Laboratory.*—A theory of the impurity photoionization magneto-optic (IPMO) effect[1] in semiconductors has been developed for impurity states associated with a simple parabolic band with minimum at $k=0$. For not too large magnetic fields the photoionization process may be regarded as the optical excitation of charge carriers from bound states little affected by the magnetic field to magnetically quantized continuum states. The photoionization spectrum then consists of a superposition of bands with spacing roughly $\hbar\omega_c = heH/m^*c$. For large magnetic fields such that $\hbar\omega_c$ is much greater than the impurity ionization energy for $H=0$, the absorption spectrum consists in part of closely spaced discrete lines and a photoionization continuum near the cyclotron resonance frequency. In addition there are discrete lines and a photoionization continuum at considerably longer wavelengths. Detailed calculations for donor impurities in InSb using wave functions of the type discussed by Yafet, Keyes, and Adams[2] will be presented.

* Present address: National Carbon Research Laboratories, Cleveland, Ohio.
[1] E. Burstein and G. S. Picus, Bull. Am. Phys. Soc. Ser. II, **2**, 57 (1957).
[2] Yafet, Keyes, and Adams, J. Phys. Chem. Solids **1**, 137 (1956).

K13. Electron Bombardment Induced Current in $P-N$ Junctions. N. SCLAR AND Y. C. KIM, *Allen B. Du Mont Laboratories, Inc.*—Silicon vapor diffused $P-N$ junctions have been mounted in cathode ray tubes and bombarded with 0–20 kev electrons. Induced currents were measured whose magnitudes depended on the electron current in the incident beam, the accelerating voltage, and the applied junction bias. The effect is similar to the photoeffect except that at accelerating voltages above about 2 kv, the junctions exhibit gain where the induced current becomes numerically larger than the incident beam current. The gain is attributed to the conversion of the energy of the beam electrons into hole-electron pairs and their subsequent collection by the junction. The gain increases with electron beam current and energy and in our present junctions attains a peak value of several thousand at accelerating voltages of about 16 kv and beam currents of about 10 microamperes. The peak in gain at 16 kv is due to the penetration of the beam electrons beyond the junction and the subsequent loss in efficiency for collection of the hole-electron pairs. Pulse studies have indicated rise times less than 0.1 microsecond and decay times of the order of 10 microseconds for the induced currents. Evidence for both a fast and slow space charge effect at higher beam currents were also found.

K14. On the Correlation Effect of 3*d*-Electrons in Ti II, Cr IV, Mn V, and Fe VI. KATSUNORI HIJIKATA,* *University of Cincinnati.*—According to the atomic orbital approximation the ^{3}H and ^{3}P of d^3 configuration should have equal energy. The difference between these energy levels which appears in the spectra of Ti II and its isoelectronics, therefore, is attributed to the correlation effect of the electrons. We expressed the 2-electron function of 3*d* electrons by

$$Nr_1^2 r_2^2 (1 + cr_{12}) e^{-k(r_1+r_2)} Y_{2m}(\theta_1\varphi_1) Y_{2m}(\theta_2\varphi_2)$$

when they are supposed to be in the same orbital, the coefficient c being determined to minimize the energy. Thus, we obtained the correlation energy as a function of the effective nuclear charge. On the other hand, we removed the effect of d^2s configuration from the experimental atomic term values and this $^3H - ^3P$ of d^3 is compared with the values calculated from the above result. The correlation correction thus obtained is applied for the other spectral terms, and F_k values are determined. The same treatment is extended to the other configurations.

* Now in Physics Department, University of Colorado, Boulder, Colorado

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FRIDAY EVENING AT 7:30

University Memorial Center

(J. W. BEAMS presiding)

Banquet of the American Physical Society

After-Dinner Speech

Scientists and Public Responsibility. A. V. ASTIN, *National Bureau of Standards.*

SATURDAY MORNING AT 9:00

Memorial Center, Forum

(B. J. MOYER presiding)

Invited Papers on High-Energy Physics

L1. Disintegration of Hyperfragments. JACK SCHNEPS, *Tufts University.* (30 min.)

L2. Experiments with Polarized Muons. VALENTINE TELEGDI, *University of Chicago.* (30 min.)

L3. Bevatron Research with the Hydrogen Bubble Chamber. HAROLD TICHO, *University of California, Los Angeles.* (30 min.)

L4. Review of Recent Developments in the Theory of Weak Interactions. SIDNEY A. BLUDMAN, *University of California, Berkeley.* (30 min.)

SATURDAY MORNING AT 9:00

Physics 104

(H. B. SILSBEE presiding)

Atomic and Nuclear Resonance

M1. Quadrupole Coupling in the Alkali Chloroiodides. C. D. CORNWELL AND R. S. YAMASAKI, *University of Wisconsin.*—Chlorine nuclear quadrupole resonances reported[1] for 8 chloroiodides occur at frequencies in the neighborhood of half that for ICl. The interpretation of those results implied that iodine resonances in these crystals should fall near the corresponding frequency of ICl. Iodine resonances have been found for $CsICl_2$, $RbICl_2$, $KICl_2 \cdot H_2O$, $KICl_2$, $CsICl_4$, $RbICl_4$, $KICl_4 \cdot H_2O$, $KICl_4$, $NaICl_4 \cdot 2H_2O$, at frequencies (average 465 Mc/sec) close to that expected. This result confirms the previous suggestion[1] that iodine is bonded primarily through p orbitals, one p orbital being used for bonding to two chlorine atoms. If it were assumed that iodine employs one pd hybrid orbital for each bond, with sufficient ionicity to fit the chlorine resonance data, the predicted iodine frequencies would be twice those actually observed. Several coefficients in an LCAO representation of the bonding MO's have been estimated from the nuclear resonance data.

[1] C. D. Cornwell and R. S. Yamasaki, Bull. Am. Phys. Soc. Ser. II, 2, 264 (1957).

M2. Ultimate Limitations on the Measurement of Noise Figures of Beam Maser Amplifiers. M. L. STITCH, *Hughes Research Laboratories.*—Several methods of measuring the noise figure of beam maser amplifiers are discussed. It is shown that in a Stark modulation technique such as employed by Gordon[1] the minimum uncertainty in noise temperature, T_N, is given by $T_N \approx (2/B^{\frac{1}{2}}\tau^{\frac{1}{2}})(T_N + T_A)$, where B is the maser band width, τ the meter time constant, and T_A the temperature of the noise source. A null-indicating source modulation technique is also discussed and this gives $T_N \approx (1/B^{\frac{1}{2}}\tau^{\frac{1}{2}}) \times [T_N + T_A + (T_R/G_1)]$ where T_R is the noise temperature of the microwave receiver and G_1 is the gain of the maser.

[1] J. Gordon communicated at the Electronic Tube Conference, Berkeley, June, 1957.

M3. Hyperfine Structure of Plutonium-239. J. C. HUBBS, R. MARRUS, W. A. NIERENBERG, AND J. L. WORCESTER, *University of California, Berkeley.**—An atomic-beam magnetic-resonance experiment has been performed to investigate the hyperfine structure of Pu^{239}. Electronic and hyperfine structure constants for the observed electronic state are found to be $J = 1$, $g_J = 1.4975 \pm 0.0010$, and $\Delta W = 7.715 \pm 0.060$ Mc. In addition, a previous assignment[1] of $\frac{1}{2}$ for the nuclear angular momentum is confirmed. The method of detection is to expose a platinum foil for 5 min to the plutonium beam. Plutonium deposition is measured by observing natural alpha decay in low-background alpha counters. Preliminary measurements indicate that the electronic state under investigation has an angular momentum of one and is probably the first excited state of a ground-state term ^7F arising from an electronic configuration $(5f)^6(6d)^2(7s)^2$. A particular transition was observed at ten separate C-field values ranging from the Zeeman to the Paschen-Back regions. The data thus obtained is found to be consistent only under the assumption that the observed transition is the double quantum one $F = \frac{3}{2}$, $m_J = \pm\frac{3}{2} \leftrightarrow m_J = \mp\frac{3}{2}$. Under this assumption, values of ΔW and g_J are fitted to the data from a modified Breit-Rabi formula. The value for ΔW is verified from an observation of the transition $\Delta F = 1$, $\Delta m = 1$. The generous assistance of B. B. Cunningham and J. C. Wallman is gratefully acknowledged.

* This work was supported by the U. S. Atomic Energy Commission.

[1] M. Van Den Berg, and P. F. A. Klinkenberg, Physica **XX**, 461 (1954).

M4. Spins of Some Radioactive Iodine Isotopes. E. LIPWORTH AND H. L. GARVIN, *University of California, Berkeley.**—The spins of iodine-123 and iodine-131 have been determined using the method of atomic beams. The isotope I^{123}, produced by the bombardment of antimony metal with alpha particles, was separated chemically from the metal, mixed with natural iodine carrier, and dissociated into atomic iodine by a discharge tube. Dissociation was essentially 100% complete. The iodine beam was detected by allowing it to fall upon silver-coated buttons that were subsequently counted. Identification of the isotope was made by its decay. The spin of the 13-hr I^{123} is $\frac{5}{2}$. The I^{131} was obtained from Oak Ridge, and the measured spin value of $\frac{7}{2}$ confirms an earlier measurement by a different method.[1]

* This work was supported by the U. S. Atomic Energy Commission.

[1] Livingston, Benjamin, Cox, and Gordy, Phys. Rev. 92, 1271 (1953).

M5. Dipole and Quadrupole Moments of Gallium-67. J. L. WORCESTER, J. C. HUBBS, AND W. A. NIERENBERG, *University of California, Berkeley.**—The magnetic dipole and electric quadrupole moments of 78-hr gallium-67,[1] $I = \frac{3}{2}$,[2] have been measured by the atomic beam resonance technique.

The isotope is produced by the Cu$(\alpha,2n)$ reaction in the Berkeley 60-in. cyclotron. Using the conventional flop-in technique, the two refocused transitions in the $^2P_{\frac{1}{2}}$ state, $F=3$, $m_F=-1\leftrightarrow-2$, and $F=2$, $m_F=0\leftrightarrow-1$, have been observed at magnetic fields from 0 to 110 gauss. The observed frequencies are used to determine the hyperfine-structure interaction constants, which are $W(F=3)-W(F=2)=\Delta\nu_{32}=597.2\pm2.6$ Mc, $\Delta\nu_{21}=278.8\pm4.0$ Mc. With the electronic matrix elements given by Becker and Kusch,[3] the nuclear moments are $\mu=1.84\pm0.02$ mm and $Q=0.213\pm0.012\times10^{-24}$ cm^2. These values are calculated by using sixth-order perturbation theory, and verified by diagonalizing the Hamiltonian with the IBM-650 computer. The assignment of a positive dipole and a positive quadrupole moment is more consistent with the observed transition frequencies.

* This work was supported by the U. S. Atomic Energy Commission.
[1] McCown, Woodward, and Pool, Phys. Rev. **74**, 1311 (1948).
[2] Hubbs, Nierenberg, Shugart, and Worcester, Phys. Rev. **105**, 1928 (1957).
[3] G. E. Becker and P. Kusch, Phys. Rev. **73**, 584 (1948).

M6. Nuclear Spin of Au^{194}.* J. B. Reynolds, R. L. Christensen,† W. M. Hooke, D. R. Hamilton, and H. H. Stroke, *Princeton University*, and W. B. Ewbank, W. A. Nierenberg, H. A. Shugart, and H. B. Silsbee, *University of California, Berkeley*.—The nuclear spin of 1 has been measured for 40-hour Au^{194} by atomic-beam magnetic resonance methods at Princeton University and at the University of California. The Princeton group employed the rotating-disk, flop-out method which was previously used in work on As^{76},[1] while the California group used the atomic-beam flop-in technique.[2] Resonances were detected and identified by counting k x-rays resulting from the radioactive decay of collected activity. At Princeton resonances have been observed at five values of the transition magnetic field, while at Berkeley resonances have been observed at three fields. The isotope was prepared from platinum by bombarding with 18-Mev protons at Princeton, 22-Mev deuterons at Brookhaven, and 12-Mev protons at Berkeley. The gold was chemically separated from the target material at Princeton, but was evaporated from the platinum target in the atomic-beam oven at Berkeley. Further work is in progress and hyperfine structure separation and magnetic moment information will be published later.

* This work was supported in part by the U. S. Atomic Energy Commission and the Higgins Scientific Trust Fund (Princeton) and by the U. S. Atomic Energy Commission and the Office of Naval Research (Berkeley).
† Charles A. Coffin Fellow 1955-1957.
[1] Christensen, Bennewitz, Hamilton, Reynolds, and Stroke (to be published).
[2] Hobson, Hubbs, Nierenberg, Silsbee, and Sunderland, Phys. Rev. **104**, 101 (1956).

M7. Nuclear Spins of Ag^{106} and Ag^{110m}. W. B. Ewbank, W. A. Nierenberg, H. A. Shugart, and H. B. Silsbee, *University of California, Berkeley*.*—The spins of 8.3-day Ag^{106} and 253-day[1] Ag^{110m} have been measured by the atomic-beam magnetic resonance flop-in method using radioactive detection.[2] The spin of each silver isotope is 6. The Ag^{106} was prepared in two ways: by (α,n) reaction on Rh^{103} and by (p,n) reaction on Pd^{105} (present in 27% abundance in the natural Pd target). The Ag^{110m} was prepared by (n,γ) reaction at the Arco reactor. The resonances of Ag^{110m} were observed seven times at five different frequencies between 2.4 and 15.7 Mc/sec. The Ag^{106} resonance was observed twice at 2.4 Mc/sec by the Pd production and once at 3.1 Mc/sec by the Rh production. The Ag^{106} was further identified by its measured half-life. The beam of Ag^{106} atoms was obtained by heating the target material in the atomic beam oven and evaporating the silver from the palladium or rhodium. Both spins are somewhat high in view of current nuclear models.

* This work is supported jointly by the U. S. Atomic Energy Commission and the Office of Naval Research.
[1] K. W. Geiger, Phys. Rev. **105**, 1539 (1957).
[2] Hobson, Hubbs, Nierenberg, Silsbee, and Sunderland, Phys. Rev. **104**, 101 (1956).

M8. Reflection Coefficient Caused by Paramagnetic Resonance.* John J. Faris and David F. Wait, *Colorado State University*.—The reflection coefficient caused by paramagnetic resonance of a free radical (diphenyl-trinitrophenyl-hydrazyl) has been observed at X band. The sample is contained in a wave guide terminated in a matched load. The apparatus makes use of a hybrid T as a microwave balanced bridge and a heterodyne detector. By suitable adjustment of the phase of the reflection from the "dummy" arm, either a pure absorption or pure dispersion signal can be obtained. These results can be understood in terms of classical electromagnetic theory with the introduction of a complex magnetic susceptibility.

* Supported by a grant from the Research Corporation.

M9. Stimulated Emission from Nuclear Quadrupole Systems. R. Braunstein, *RCA Laboratories*.—If in a system of at least three energy levels, transitions are allowed between the lowest and the highest level, the power saturation of this transition can result in a net emission of radiation between the intermediate level and either of the two saturated levels.[1,2] This technique has been applied to a paramagnetic substance to produce a solid-state "maser."[3] A nucleus of spin $I\geq\frac{3}{2}$ or ≥2 possessing an electric quadrupole moment when present in a crystalline electric field of lower than cubic symmetry yields at least three unequally spaced energy levels. If the crystalline field has large deviations from axial symmetry, $\Delta|M|=2$ as well as $\Delta|M|=1$ transitions are possible. The saturation of the $\Delta|M|=2$ transition can result in the inversion of the normal population of the energy levels which can be detected by nuclear resonance where a stimulated emission would be observed rather than a resonance absorption. In a number of solids that exhibit pure quadrupole resonance, the conditions exist for the possibility of producing a pure quadrupole "maser."

[1] N. G. Basov and A. M. Prokhorov, J. Exptl. Theoret. Phys. U.S.S.R. **28**, 249 (1955).
[2] N. Bloembergen, Phys. Rev. **104**, 324 (1956).
[3] Scovil, Feher, and Seidel, Phys. Rev. **105**, 762 (1957).

M10. Hyperfine Interactions in F-Electron Spin Resonance. F. J. Adrian, *Applied Physics Laboratory, The Johns Hopkins University*,* and W. E. Blumberg, and T. P. Das,† *University of California*.—A recent calculation of isotropic magnetic hfs constants associated with F-electron spin resonance has utilized a simple F-electron wave function, which had been orthogonalized to the ion core orbitals by the Schmidt process.[1] The non-orthogonal wave function was computed variationally using a point ion lattice model. We have extended this calculation to include the anisotropic magnetic hfs constant and the quadrupole coupling constant for the nearest neighbor positive ions. Feher has recently determined these quantities for KCl using a double-spin-resonance method.[2] Results for K^{39} in KCl, in Mc/sec, and Feher's notation, are: $a=35$, $b=1.0$, and $-0.1>Q'>-0.3$ depending on one's choice of several constants which enter the calculation. Results for the Na^+ ion in NaF and NaCl will also be presented.

* Work supported by the Bureau of Ordnance, Department of the Navy, under NOrd 7386.
† Work supported by the Office of Naval Research and the National Security Agency.
[1] B. S. Gourary and F. J. Adrian, Phys. Rev. **105**, 1180 (1957).
[2] G. Feher, Phys. Rev. **105**, 1122 (1957).

M11. Paramagnetic Resonance in Electron-Irradiated Barium Chlorate. J. A. Cowen, *Michigan State University*.—The paramagnetic resonance spectrum of single crystals of $Ba(ClO_3)_2\cdot H_2O$, $NaClO_3$, $Na_2S_2O_3\cdot5H_2O$, $CaSO_4\cdot2H_2O$, $MgSO_4\cdot7H_2O$, $BaCl_2$ and of polycrystalline samples of $Ba(BrO_3)_2H_2O$ irradiated with 1-Mev electrons has been observed. The spectrum of $Ba(ClO_3)_2\cdot H_2O$ is the most complex, exhibiting 12 lines asymmetrically placed about a free electron g value. The maximum splitting is 140 gauss above and 70

gauss below the zero field value. The angle dependence upon rotation about the c axis indicates two nonequivalent sites in the lattice separated in angle by approximately 50°. This agrees with the positions of the chlorate groups as determined by Kartha.[1] The resonance in powdered $Ba(ClO_3)_2 \cdot H_2O$ is different from that in powdered $Ba(BrO_3)_2 \cdot H_2O$.

[1] G. Kartha, Proc. Indian Acad. Sci. Sect. A, **36**, 501 (1952).

M12. Low Field Electron Spin Resonance in a Sodium-Liquid Ammonia Solution.* W. WYSOCYANSKI† AND J. A. COWEN, *Michigan State University.*—Apparatus has been designed and constructed for observing electron spin resonance at magnetic fields from 0.3 to 30 gauss (frequencies from 0.75 to 7.5 Mcps). The radio-frequency spectrometer consists of a modified Pound-Knight circuit. A modulated static magnetic field for resonance is provided by a pair of Helmholtz coils, while the stray field of the laboratory is "bucked out" to within 0.0005 gauss by a second set of coils. The apparatus has been used to study the variation of spectroscopic splitting factor (g factor) in the organic free radical diphenyl picrylhydrazyl (DPPH), and in a 0.23 molar solution of sodium in liquid ammonia. The g value in the DPPH was found to vary in a manner similar to that obtained by Garstens‡; while in the sodium solution, g was observed to be constant over the range studied, with a value of 2.002 ± 0.002.

* Supported by a grant from the National Science Foundation.
† Now at Convair, San Diego, California.
‡ Garstens, Singer, and Ryan, Phys. Rev. **96**, 53 (1954).

M13. Ultrasonically Induced Spin Transitions of I and Na in NaI.* O. KRAUS† AND W. H. TANTTILA, *Michigan State University.*—Ultrasonic waves have been used to cause $\Delta m = \pm 2$ transitions between Zeeman levels of Na and I in a single crystal of NaI. Using techniques similar to those described elsewhere[1] the attenuation of the free induction decay caused by the ultrasonic saturation was measured as a function of ultrasonic energy density. Both the Na and I measurements were made at 5 mc. A theory based on the assumption of a fast mutual spin-flip process, and a well defined spin temperature, is used in conjunction with the thermal and ultrasonic transition probabilities to calculate γ using the six-point charge model of Van Kronendonk.[2] The results reported are γ_I/γ_{Na}. This ratio for the ultrasonic processes is 13. The same ratio is calculated from Van Kronendonk's theory for the γ's associated with thermal processes and is shown to be less by a factor of 2. Measured relaxation times T_1 for Na and I are 5 and 0.006 seconds, respectively.

* Work supported by the National Science Foundation.
† Now at National Bureau of Standards, Washington, D. C.
[1] W. G. Proctor and W. A. Robinson, Phys. Rev. **104**, 1344 (1956).
[2] J. Van Kronendonk, Physica **20**, 781 (1954).

M14. Nuclear Magnetic Resonance and Transitions in Irradiated and Unirradiated Polyethylene. J. A. SAUER AND N. FUSCHILLO, *Pennsylvania State University.*—Nuclear magnetic resonance line shapes have been observed in specimens of polyethylene irradiated in the Brookhaven Reactor to 8.3×10^{18} nvt. Line shapes have also been observed as a function of temperature in unirradiated polyethylene and in polyethylene irradiated to 100 mr in a Co^{60} source. As the temperature is raised from liquid nitrogen values, a central narrow component becomes superimposed on the broad line which has a width of about 14 g. This narrow line has a width of about 5 g at low temperatures and undergoes a further reduction to the value of the magnetic field in homogeneity starting at about 235°K. The first appearance of the narrow line and the subsequent decrease at higher temperatures are attributable respectively to the onset of rotation of the methylene units and to subsequent diffusional or "neo-Brownian" motions of chain segments in the amorphous regions. For the irradiated samples at room temperature the narrow line first increases in magnitude and then decreases and broadens. This behavior is interpreted as a result of the loss of crystallinity upon irradiation and the subsequent increase of rigidity with further irradiation, that is produced by the primary crosslinks that form as a result of ionization and hydrogen removal. The NMR results are discussed and compared with specific volume data and dynamic mechanical data taken on the same polyethylene.

M15. Experimental Evaluation of the Oxygen Microwave Absorption as a Possible Atomic Frequency Standard. JOHN M. RICHARDSON, *National Bureau of Standards, Boulder.*—A microwave line of O_2 near 60 000 Mc was suggested by Townes (1951) as a possible atomic frequency standard suitable for synchronizing an oscillator. With the advent of cesium beam resonators and masers, the expected usefulness of the O_2 absorption as an ultraprecise standard diminished; nevertheless a quantitative experimental evaluation was desirable to compare the various devices. Theoretical design, actual design, and results for an oxygen microwave spectrometer for use as a discriminator in a frequency control loop are described. Essential characteristics are the variation of discriminator output signal with frequency, and the discriminator output noise level. General expressions for these quantities for a wide range of experimental arrangements are obtained, and may be used to predict the degree of frequency control attainable by a loop. Characteristics in complete agreement with the expected values, capable of control to less than 1 part in 10^9 were observed with relatively crude apparatus. Improvement by a few orders of magnitude can be confidently expected by engineering refinements. It is likely, however, that oxygen will lag cesium beams and masers as a desirable standard, mainly because of its much larger line width, which requires more complicated apparatus to exploit.

Supplementary Programme*

M16. Electronic States of F_2 Calculated by the Method of Atoms in Molecules, and the Magnetic Shielding Constant of Fluorine Molecule. KATSUNORI HIJIKATA,* *Harvard University.*—The method of atoms in molecules is applied for F_2. All the electrons and all the atomic structures arising from the arrangement of the second quantum electrons are taken into account. The calculation was done for the internuclear distances 1.221 and 1.526 A. The electronic energy thus obtained is compared with the result of the ASMO treatment.[1] Discussions are tried for the excited states. It has turned out that this method critically depends on the approximation of the overlap integrals of the composite atomic functions. The magnetic shielding constant of the fluorine molecule is calculated on the basis of the results of MAM and ASMO. Both methods naturally give smaller value than that obtained by Saika and Slichter.[2]

* To be given after Session M if Chairman rules that there is sufficient time.

* Now in Physics Department, University of Colorado, Boulder, Colorado.
[1] Reported at 1957 Southwestern Meeting, Norman, Oklahoma.
[2] A. Saika and C. P. Slichter, J. Chem. Phys. **22**, 26 (1954).

M17. Empirical Formula for Inversion Spectrum of Ammonia.* T. E. KILPATRICK AND M. MIZUSHIMA, *University of Colorado.*—An empirical formula for the inversion spectrum has been given by Costain.[1] More recently, additional data has been obtained, particularly by Nishikawa and Shimoda.[2] These authors have pointed out a systematic deviation from Costain's formula. A revised formula is being calculated, taking into account the more recently available data.

* This research is supported by the National Science Foundation.
[1] C. C. Costain, Phys. Rev. **82**, 108 (1951).
[2] F. Nishikawa and K. Shimoda, J. Phys. Soc. Japan **10**, 89 (1955).

SATURDAY AFTERNOON AT 1:00

Memorial Center, Forum

(D. A. LIND presiding)

Invited Papers on Cyclotrons

N1. Los Alamos Variable Energy Cyclotron: Design Considerations. KEITH BOYER, *Los Alamos Scientific Laboratory.* (30 min.)

N2. Los Alamos Variable Energy Cyclotron: Installation and Experimental Facilities. THOMAS M. PUTNAM, JR., *Los Alamos Scientific Laboratory.* (30 min.)

N3. Design Modifications of the Illinois 43-Inch Cyclotron to Adopt Spiral Ridge Focusing. JAMES S. ALLEN, *University of Illinois.* (30 min.)

N4. Some Design Features of the Colorado Variable Energy Cyclotron. J. J. KRAUSHAAR, *University of Colorado.* (30 min.)

SATURDAY AFTERNOON AT 1:00

Physics 104

(R. L. PETRITZ presiding)

Invited Papers on Solid-State Physics

O1. Statistical Fluctuations in Semiconductors. R. E. BURGESS, *University of British Columbia.* (30 min.)

O2. Thermodynamic Approach to Generation-Recombination Noise in Semiconductors. K. M. VAN VLIET, *University of Minnesota.* (30 min.)

O3. Theory of Noise Processes in Diodes and Transistors. D. O. NORTH, *RCA Laboratories.* (30 min.)

O4. Experimental Investigations of Excess Noise in Semiconductors. J. J. BROPHY, *Armour Research Foundation.* (30 min.)

SATURDAY AFTERNOON AT 1:00

Hellems 111 E

(M. IONA presiding)

Mesons and Cosmic Rays

P1. Negative μ-Meson Mean Life in Fe.* W. A. BARRETT, F. E. HOLMSTROM, AND J. W. KEUFFEL, *University of Utah.*—A cosmic-ray beam of slow μ mesons is selected by a telescope of Čerenkov counters, Geiger counters, and lead filter. A negative μ stopping in an iron target and captured by an Fe nucleus yields an evaporation neutron detected by a large liquid scintillator S_4. The distribution of delay times between the arrival of stopping μ's and detection of neutrons in S_4 is measured. Background arises from three sources: (1) contamination of μ beam leading to short time lags (2) random noise in S_4 and (3) delayed bremsstrahlung from positive μ's stopping in the target. The target is a sandwich of thin iron plates and plastic scintillators. A positive μ yields a decay electron which may be detected in the sandwich, thus minimizing background source (3). The result of a run of 355 hours is 1355 (total) μ^--capture events, with a good fit to an exponential distribution of 0.242 ± 0.015 μsec mean life. Ratio of useful μ-capture event rate to all background is about 10. The μ-beam contamination is very low. The results of this experiment will be compared with those of electron counting experiments performed at Columbia.

* Assisted by the National Science Foundation and by the University Research Committee.

P2. Experimental Test of the Fermi-Teller "*Z* law."* D. D. YOVANOVITCH, J. C. SENS, R. A. SWANSON,† AND V. L. TELEGDI, *University of Chicago.*—The ratio of μ^- captures into the various atomic species of a binary chemical compound $A_1(Z_1)_nA_2(Z_2)_m$ should according to Fermi and Teller[1] be Z_1n/Z_2m. Once a μ^- meson has been captured into a given atom, its fate is decided by the ratio of *nuclear* capture and free decay rates in the K orbit around the nucleus Z in question. Since the nuclear capture goes as Z_{eff}^4, one can decompose electron decay curves obtained with μ^- stopping in compounds to determine the *atomic* capture ratios. We obtained such decay curves using time-to-pulse height converters[2] covering in each case about 3 lifetimes of the longer component. Graphical analysis of these curves, each comprising $\cong 3\cdot10^4$

real counts, yielded: Al_2O_3, O/Al≃3 (1.1); CCl_4 (1), Cl/C≃5 (11.3); NaCl≃1 (0.65); P_2O_5, O/P≃3.5 (1.30); KHF_2, F/K≃2 (1.05); $Cl_3C_6H_4$, C/Cl≃3 (1.06). The numbers in brackets are the ratios predicted by the "Z law." More accurate experimental ratios based on l.s. fits to the data will be presented, but it is clear already that the simple molecular ratios are closer to the observed facts in all cases.

* Research supported by a joint program of the Office of Naval Research and the U. S. Atomic Energy Commission.
† National Science Foundation Fellow, 1956–1957.
[1] E. Fermi and E. Teller, Phys. Rev. 72, 399 (1947).
[2] Swanson, Campbell, Garwin, Sens, Telegdi, Wright, and Yovanovitch, Bull. Am. Phys. Soc. Ser. II, 2, 205 (1957).

P3. Re-Establishment of μ^+ Polarization in Depolarizing Media by an External Magnetic Field.* R. A. Swanson,† J. C. Sens, V. L. Telegdi, and D. D. Yovanovitch, *University of Chicago.*—It has been shown[1–3] that the decay of polarized μ^+ mesons yields an electron angular distribution of the form $1-a\hat{p}_\mu\cdot\hat{p}_e$, a depending strongly on the stopping medium. Time-analyzed precession experiments[2,3] prove that the depolarizing processes occur in much less than 10^{-6} sec and are over by the time the μ^+'s are thermalized. The coupling of the μ^+ moment to electronic moments (say, in muonium) provides the only conceivable and adequate mechanism. The possibility of decoupling from these moments by a longitudinal external field B is apparent.[4] We demonstrated this in 50% depolarizing (emulsion[5]) and 100% depolarizing media (fused quartz) by counter techniques. The dependence of a on B was measured between zero and 7 kgauss. In either material, about 75% of the initial polarization was recovered in the highest B used. The observed B dependence excludes single muonium formation; other mechanisms, capable of producing such a dependence, will be discussed.

* Research supported by a joint program of the Office of Naval Research and the U. S. Atomic Energy Commission.
† National Science Foundation Fellow, 1956–1957.
[1] Garwin, Lederman, and Weinrich, Phys. Rev. 105, 1415 (1957).
[2] Swanson, Campbell, Garwin, Sens, Telegdi, Wright, and Yovanovitch, Bull. Am. Phys. Soc. 2, No. 4, 205 (1957).
[3] Cassels *et al.*, University of Liverpool (in print).
[4] G. Goertzel, Phys. Rev. 70, 897 (1946).
[5] The Columbia and Berkeley emulsion groups have independently found, by direct track measurements on plates exposed in high fields, a substantial increase in a.

P4. Average Multiplicity and Inelasticity in Pion Production in the Atmosphere. Kaichi Maeda, *University of Nebraska*, and George Ishikawa, *Meteorological Research Institute, Tokyo.*—By using the empirical formula of the energy spectrum of primary cosmic rays given by Barrett, Bollinger, *et al.*,[1] and the production spectrum of muons given by Olbert,[2] the average multiplicity of pion production in the atmosphere is estimated for the energies from 20 Bev up to 10^3 Bev. In this estimation, the general case of nucleus-nucleus collision is considered in order to get the energy relation between an incident primary particle and the produced pions. For the actual calculation of multiplicity by this consideration, however, we assumed the several values of inelasticity to be independent of incident energy. The results are summarized as follows: inelasticity in meson production by nucleus-nucleus collision is, perhaps, below 0.2 if we assume it to be energy independent. In this case, the energy-dependence of multiplicity is the same as predicted by Fermi[3] and Landau;[4] i.e., it is proportional to the one-fourth root of incident energy.

[1] Barrett, Bollinger, Cocconi, Eisenberg, and Greisen, Revs. Modern Phys. 24, 133, (1952).
[2] S. Olbert, Phys. Rev. 96, 1400 (1954).
[3] E. Fermi, Progr. Theoret. Phys. 5, 570 (1950).
[4] S. Z. Belen'ki and L. D. Landau, Nuovo cimento, Suppl. III, Ser. X, 15 (1956).

P5. Photomeson Production from Hydrogen and Deuterium. E. A. Knapp, R. W. Kenney, V. Perez-Mendez, and W. A. Perkins, *University of California, Berkeley.**—The relative yields of positive pions produced from hydrogen and deuterium by the 340-Mev bremsstrahlung beam of the Berkeley synchrotron have been measured at lab angles of 20°, 40°, and 60°. The pions were identified in a counter telescope by their characteristic $\pi-\mu$ decay, and measurements were done at pion energies (lab) ranging from 45 Mev to 145 Mev. The ratio of the relative yields of pions from deuterium and hydrogen was roughly constant as a function of angle, but decreased monotonically with pion energy from a value of 0.9 ± 0.05 at 45 Mev to a value of 0.55 ± 0.07 at 145 Mev. The data will be interpreted in terms of spin-flip and no-spin-flip interactions as evaluated in the phenomenological theory of Chew and Lewis.[1] Our data indicate a transition from a spin-flip interaction at the lower pion energies and smaller angles to a no-spin-flip interaction at the higher energies and wider angles.

* This work was performed under the auspices of the U. S. Atomic Energy Commission.
[1] G. F. Chew and H. W. Lewis, Phys. Rev. 84, 779 (1951).

P6. Photoproduction of π^0 Mesons at High Energies.* R. M. Worlock and A. V. Tollestrup, *California Institute of Technology.*—The photoproduction of single π^0 mesons from hydrogen is being studied at the Caltech synchrotron laboratory at photon energies between 600 Mev and 1 Bev. The experiment to be described determines the cross section by counting recoil protons from the liquid hydrogen target placed in the synchrotron bremsstrahlung beam. The protons at five different laboratory angles from 20° to 60° are counted by a five counter telescope which comprises a standard three counter range telescope plus an additional dE/dx counter for more positive identification of the proton and a Čerenkov counter in anticoincidence to eliminate events due to multiple electrons. Errors due to counting recoil protons from multiple pion production are kept small by reducing the synchrotron energy so the bremsstrahlung spectrum extends to only slightly higher energy than that of the photons producing the desired events. Preliminary data indicate that, rather than peaking forward as is observed at 400 Mev, the 700-Mev π^0 angular distribution tends to peak slightly back of 90° in the center-of-mass system. The excitation curve, after falling rapidly from the 300-Mev resonance, is relatively flat from 600 Mev to 1 Bev. Two points on the 600-Mev angular distribution are: θ_π c.m. equal 93° and 115° have differential cross sections of 4.2 ± 0.4 and 4.7 ± 0.3 microbarns per steradian, respectively.

* This work was supported in part by the U. S. Atomic Energy Commission.

P7. Photoproduction of Neutral Mesons at High Energies: Magnet Method.* J. I. Vette and W. D. Wales, *California Institute of Technology.*—The photoproduction of neutral mesons by the process $\gamma+P\rightarrow\pi^0+P$ is being studied in the 500–950 Mev photon energy range. The recoil protons from a liquid hydrogen target bombarded by the bremsstrahlung of the Caltech synchrotron are detected by three plastic scintillation counters placed at the forcus of a magnetic spectrometer. The contamination by protons recoiling from multiple meson production is reduced to less than 10% by keeping the maximum energy of the bremsstrahlung about 150 Mev above the photon energy being studied. At a meson center-of-mass

Table I.

Photon energy (Mev)	$\theta_{\pi\ \mathrm{cm}}$	$(d\sigma/d\Omega)$ cm 10^{-30} cm²/sterad
520	45°	4.73 ± 0.30
620	45°	2.44 ± 0.15
780	45°	2.32 ± 0.15
940	45°	2.26 ± 0.15

* This work was supported in part by the U. S. Atomic Energy Commission.

angle of 45° the rapid decrease of the cross section above the resonance energy ceases abruptly around 600 Mev and remains approximately constant out to 950 Mev. The results in this region are presented in Table I.

P8. Photoproduction of Pion Pairs in Hydrogen.* MICHEL BLOCH AND MATTHEW SANDS, *California Institute of Technology.*—The multiple production of pions is observed by detecting in a magnetic spectrometer the negative pions which emerge at 60° from a high-pressure hydrogen target in the bremsstrahlung beam of the Caltech synchrotron. The data for a maximum photon energy of 600 Mev agree with the Stanford results.[1] The yield (per effective photon) of 50-Mev pions rises rapidly from 500 to 700 Mev and more slowly between 700 and 1100 Mev in qualitative agreement with the Cornell results at 35°.[2] The yield of 150-Mev pions increases nearly linearly from 600 to 1100 Mev. The cross section for negative pion production (obtained for *each* photon energy by subtraction) is, when integrated over the *pion* energy, consistent with a constant value of 5×10^{-30} cm²/sterad (lab) for photon energies from 550 to 1100 Mev. Results will also be reported for mesons at 120°.

* This work was supported in part by the U. S. Atomic Energy Commission.
[1] R. M. Friedman and K. M. Crowe, Phys. Rev. **105**, 1369 (1957).
[2] Woodward, Wilson, and Luckey, Bull. Am Phys. Soc. Ser. II, **2**, 195 (1957).

P9. Search for the Decay of Mass-550 Particles. R. L. CALL AND J. W. KEUFFEL, *University of Utah.**—An experiment designed to detect the mass-550 particles reported by Alikhanian *et al.*[1] is in operation at altitude 4700 ft. An incident telescope containing a Čerenkov anticoincidence counter and a thin scintillator select slow particles and measure their velocities. The particles stop in a thin-walled 64-kg liquid scintillator enclosed by a scintillator jacket in anticoincidence. The pulse from the 64-kg scintillator plus the velocity measurement determine the mass with fair resolution. The time and energy pattern of the pulses from each event is presented in detail on an oscilloscope during a gate of 0.06 sec. Preliminary results based on a week of running are as follows:—If the positive mass-550 particle has a mean life $\tau<5$ msec, its abundance relative to μ^+ in the same range interval is .0.5%, assuming any reasonable decay scheme. If the particle decays into μ^+ or π^+, its abundance is $<0.3\%$ if $\tau<0.05$ sec, and $<0.1\%$ if $\tau<5$ msec.

* Assisted by the National Science Foundation and the University Research Committee.
[1] Alikhanian *et al.*, Zhur. eksptl. i Teoret. Fiz. **31**, 955 (1956).

P10. Search for Subionizing Particles with Wilson Cloud Chambers.* H. C. FITZ, JR.,† W. B. GOOD, J. L. KASSNER, JR., AND A. E. RUARK, *University of Alabama.*—Since ionization due to a charged particle varies with the square of its charge, a very clean cloud chamber can be used to search for particles having charge ze much less than the electronic charge. Similar remarks hold true concerning energetic magnetic monopoles. A long sensitive-time horizontal cloud chamber kindly loaned by Professor J. A. Bearden has been successfully used to search for such particles. The background is at least 100 times less than values commonly reported for "clean" chambers. No subionizers with z in the range $\frac{1}{4}$ to $\frac{1}{2}$ were seen during a time in which 10^9 gamma rays traversed the chamber. A vertical chamber 12 in. high was also used; its background ranged from 0.05 to 1.0 drop per cc, but techniques for a more limited search were developed. No suspected subionizers appeared in preliminary work using only cosmic rays. Results will be presented, and a reasonable explanation will be given for the levels of background for both chambers.

* Work supported by a National Science Foundation Grant.
† Authors now at Sandia Base, Baylor University, Missouri School of Mines, and U. S. Atomic Energy Commission, respectively.

P11. 6.2-Bev Proton-Proton Collisions in Nuclear Emulsions.* J. J. LORD, R. M. KALBACH, Y. B. KIM, AND C. H. TSAO, *University of Washington.*—About 500 events have been found in Ilford G-5 emulsions which looked like proton-proton collisions but, by analysis, only about half of these were determined to be collisions with free protons of the emulsion. The elastic *p-p* collisions were analyzed first and a total of 24 cases considered. The number of scatterings for center-of-mass angular intervals 0.0°–18.2°, 18.2°–25.8°, and 25.8°–31.8° were found to be 65, 4, 1, and 0, respectively. The number of events in the first angular interval is corrected for the scanning efficiency. This angular distribution in comparison with various optical models is in general agreement with models used at Cosmotron energies. The particles emitted in 2 and 4 prong inelastic collisions have been analyzed with the aid of grain density and scattering techniques. The angular distribution of the charged pions in these two types of events appears to be spherically symmetric in the *C* system. In the case of the 2 pronged inelastic events, the angular distribution of the protons is quite peaked in the forward and backward directions and charged pion production is considerably more rare than predicted by meson production theories.

* Assisted by the joint program of the Office of Naval Research and the U. S. Atomic Energy Commission and a grant from the National Science Foundation.

P12. Atmospheric Effects of the Hard Component of Cosmic Radiation Near Sea Level.* W. R. FRENCH, JR.,† AND R. L. CHASSON, *University of Nebraska.*—The atmospheric effects on the hard component of the cosmic-ray intensity were studied experimentally at Lincoln, Nebraska, using narrow- and wide-angle Geiger-counter telescopes with 20-cm lead absorber. Measurements were made over a three-year period, and four types of triple-regression calculations were performed using different atmospheric models. These were 50 mb Duperier,[1] 100 mb Duperier, 200 mb Duperier, and Olbert[2] analyses. It is concluded that the 50 mb Duperier model is superior to the others tested, but the extent to which the atmospheric effects can be eliminated by statistical methods is limited at present by the accuracy of the radiosonde data. Comparisons of results with those of other investigators show general agreement. The results of the present work are in good agreement with the theoretical temperature-effects work of Trefall,[3] are in poor agreement with his barometric-effects predictions, and do not substantiate the theoretical work of Olbert.[3]

* Supported by Research Corporation grant to W.R.F. and University of Nebraska Research Council grant to R.L.C.
† Now at Nebraska Wesleyan University, Lincoln, Nebraska.
[1] A. Duperier, J. Atmospheric and Terrest. Phys. **1**, 296 (1951).
[2] S. Olbert, Phys. Rev. **92**, 454 (1953).
[3] H. Trefall, Proc. Phys. Soc. (London) **68**, 625; **68**, 893; **68**, 953 (1955).

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Preliminary Announcement of the 1957 Thanksgiving Meeting at St. Louis

As happens every few years, so in 1957 the Thanksgiving meeting of the American Physical Society is transposed from its more usual habitat to Washington University, St. Louis. The dates will be Friday and Saturday, November 29 and 30, 1957. Rooms have been set aside for our members, at the flat rates of $7 for singles and $13 for twin beds, in the Coronado Hotel, 3701 Lindell Boulevard.

Deadline will be Friday, September 27. Abstracts are to be sent to Karl K. Darrow, American Physical Society, Columbia University, New York 27, New York.

Announcement of the Tenth-Anniversary Meeting of the Division of Fluid Dynamics

The Division of Fluid Dynamics of the American Physical Society will hold its tenth-anniversary meeting at Lehigh University, Bethlehem, Pennsylvania, on Monday, Tuesday, and Wednesday, November 25, 26, and 27. Deadline is Friday, October 11. Abstracts are to be sent to Dr. F. N. Frenkiel, Applied Physics Laboratory, Johns Hopkins University, Silver Spring, Maryland. Notices will be sent to members of the Division.

MEETINGS AND DEADLINES UP TO THE 1958 ANNUAL MEETING

Place	*Meeting dates*	*Deadline date*
St. Louis	November 29–30	September 27
Stanford,* California	December 19–21	October 18
New York	January 29–February 1	November 15

* Abstracts for the Stanford meeting are to be sent to W. A. NIERENBERG, University of California, Berkeley 4, California, and must reach his office not later than the corresponding deadline date.

Abstracts for the other meetings listed above are to be sent to KARL K. DARROW, American Physical Society, Columbia University, New York 27, New York, and must reach his office not later than the corresponding deadline date. Take note that abstracts mailed the day before deadline-day often fail to arrive in time: the last postal delivery of the day usually comes to our office before 2 P.M. Allow at least two days for abstracts sent by airmail from points east of the Mississippi, and longer for those sent from farther west. To avoid chance of confusion, please do not send an abstract for any meeting until the deadline date of the previous meeting is at least five days past. *The privilege of contributing papers to meetings of the American Physical Society is restricted to the members of the Society and to nonmembers whose papers are sponsored by members.*

RULES AND INSTRUCTIONS FOR THE PREPARATION OF ABSTRACTS

The Council has ordered that abstracts shall be not longer than two hundred (200) words or the equivalent thereof. In reckoning equivalence, a footnote is equated to ten words; each line in a table to ten words; a "display" formula—one that requires a line to itself—is an expensive luxury equated to forty words.

Two copies of each abstract must be sent to the appropriate office. They must be typewritten; one must be an original, the other may be an original or a carbon copy. *They must be double-spaced:* single-spaced manuscripts are too crowded to permit the editorial markings to be made with ease and clearness. Each abstract must be confined to a single page: if it is too long for a single page it is too long to be printed. *If we receive an abstract typed on two pages, we print only its first page.* Write each abstract as a single paragraph: the suppression of paragraphs costs time and labor to the editors. Do not use very thin paper; a sheet of very thin paper may cause extraordinary trouble when mixed with sheets of reasonable thickness. Look at the abstracts in this *Bulletin* to see how the title of the paper and the name of the author are to be arranged, and follow the example. Issues of the *Bulletin* are always appreciably delayed because the editors have to do what the authors should have done.

Remember the rule of the Council that, if an author submits more than one abstract, all but one must go onto the Supplementary Programme. In enforcing this rule, an abstract is credited to the author whose name appears first in the by-line. **By action of our Council, abstracts will not henceforth be withdrawn from our proofs unless the asker sends ten dollars with his request.**

Next winter we shall begin to levy a stiff charge for all corrections made upon text or proofs of abstracts, since these have become so numerous as to delay the *Bulletin*. Start now to form the habit of getting your abstract right before you send it in.

Report of the Nominating Committee

A meeting of the Nominating Committee for officers in the American Physical Society was held in the West Room of the Shoreham Hotel at 4:00 p.m. on Thursday, April 25. Those present were: J. L. Fowler, S. A. Goudsmit, Thomas Lauritsen, W. J. Lyons, K. G. McKay, E. M. Purcell, R. R. Wilson, and J. H. Van Vleck (*chairman*).

Nominated by the Nominating Committee and the Society at Large

President: Jesse W. Beams
Secretary: Karl K. Darrow
Treasurer: Shirley L. Quimby

Nominated by the Nominating Committee

Vice-President: George E. Uhlenbeck

Board of Editors of *The Physical Review:*

(Six positions to be filled)

Peter G. Bergmann
Melvin Lax
Francis E. Low
Maria Goeppert-Mayer
Arthur H. Snell
John Willard Stout, Jr.

Board of Editors of the *Reviews of Modern Physics:*

(Two positions to be filled)

D. R. Inglis
Philip Morrison

Members of the Council:

(Two positions to be filled)

Walter H. Brattain
William A. Fowler
Charles Kittel
Charles H. Townes
John H. Williams
Clarence Zener

Proceedings of the American Physical Society

Minutes of the Spring Meeting of the New England Section at Tufts University, Medford, Massachusetts, on April 6, 1957

THE New England Section of the American Physical Society held its annual spring meeting on Saturday, April 6, at Tufts University, Medford, Massachusetts. A total of 99 persons registered at the meetings. At the morning session nine contributed "ten-minute papers" were presented. At the afternoon session the following stimulating invited papers were heard:

Infrared Cyclotron Resonance and Magneto-Absorption in Solids. Benjamin Lax, *Lincoln Laboratory.*

Cambridge Electron Accelerator. M. Stanley Livingston, *MIT.*

Satellites. F. L. Whipple, *Harvard University.*

Robert F. Kingsbury, *Secretary-Treasurer*
New England Section

1. Induced Transverse Nuclear Magnetization by Double Resonance in Two-Spin Solids.* P. P. Sorokin† and N. Bloembergen, *Harvard University.*—Application of an rf field $\mathbf{H}_A$ at the nmr frequency ν_A of the "A" spins together with an additional rf field $\mathbf{H}'$ at the frequency $\nu' = \nu_B \pm \gamma_A|\mathbf{H}_A|$ does produce, by virtue of the coupling between the two spin systems, a steady-state transverse component of magnetization $\mathbf{M}_A$ of the "A" spins which is polarized either along or opposite to $\mathbf{H}_A$ depending on whether ν' is less or greater than ν_B. This transverse magnetization which is of the order of the equilibrium magnetization in the field $(\gamma_B/\gamma_A)H_0$ can be built up quickly, and then the usual free induction decay can be observed following the removal of both rf fields. By turning off only $\mathbf{H}'$ the transverse magnetization decay time T_{2E} characteristic of large rf fields[1] can be studied as a function of $|\mathbf{H}_A|$. These experiments were done in CsBr and CsI single crystals with the Cs^{133} nuclei as the "A" spin system. Results are discussed and interpreted with the aid of a simple model.

* This work was supported by the Office of Naval Research.
† Standard Oil of California Fellow in Applied Physics.
[1] A. G. Redfield, Phys. Rev. **98**, 1787 (1955).

2. On the Solution of Partial Differential Equations of Theoretical Physics by Monte Carlo Methods. V. Punga, *RPI Hartford Graduate Center.*—In this paper the author discusses the various interpretations of Monte Carlo solutions of partial differential equations of mathematical physics including his own researches. The procedure of solution by means of a high-speed digital computer is also outlined.

3. Deuteron Capture and Stripping in Uranium: Fission Yields of Natural Uranium with Deuterons of 5, 10, and 13.6 Mev.* J. M. Alexander, *MIT*, and T. T. Sugihara, P. J. Drevinsky, and E. J. Troianello, *Clark University.*—The relationship between valley-to-peak yield ratio in asymetric fission and excitation energy has been pointed out many times. This empirical correlation is used to estimate the excitation energy of the fissioning nuclei when uranium is bombarded with deuterons of 5, 10, and 13.6 Mev. It is concluded that at the higher energies fission predominantly follows deuteron capture although that following a stripping reaction is not negligible. A calculation based on a consideration of formation cross sections of excited nuclei by capture and stripping and the probabilities of various modes of de-excitation indicates that with 14-Mev and 20-Mev deuterons the fraction of observed fission events following d-capture is 0.75 ± 0.25. The fission cross section and the average number of neutrons emitted, $\bar{\nu}$, were measured to be as follows at the three deuteron energies:

E_d	5 Mev	10 Mev	13.6 Mev
σ_f, mb($\pm$30%)	3.5	86	430
$\bar{\nu}$	3.5 ± 0.5	5.0 ± 0.5	5.0 ± 0.5

The cross sections include the contribution of fast-neutron induced fission, which is small at the two higher energies but constitutes nearly all of the fission observed at 5 Mev. The number of neutrons emitted in a highly asymmetric fission mode has been found to be smaller than in the most probable mode.

* Supported in part by the U. S. Atomic Energy Commission at MIT and by the National Science Foundation at Clark University.

4. A High-Power, Wide-Range Saturable Core Inductor. Peter H. Rose,* *Birmingham University.*—The problem of turning the Cee of the Birmingham proton synchrotron to reduce the rf power requirements led to the development of a ferrite cored reactance with the properties shown in Table I.

Table I.

Material of core	Mullard	$F \times 1076/A3$
Inductance of cavity-air cored		0.025 μH
Maximum inductance at 0.3 Mc/sec		26 μH
Minimum inductance at 9.6 Mc/sec		0.033 μH
Peak dc bias		7000 amp-turns
Q over frequency range 0.3 Mc/sec 9.6 Mc/sec		10
rf power level		60 kva
Duty cycle		1 sec in 10 sec

The wide range of inductance was achieved using a coaxial cavity fed in the center with the rf power. The cavity is filled with 36 ferrite rings on either side of the center feed. Skin effect prevents any rf field leaking outside the walls of the cavity, and coupling with the bias winding which passes inside the center conductor of the coaxial cavity therefore does not occur. The bias current and hence the inductance is varied in a controlled manner to suit the tuning requirements of the rf system as the acceleration frequency of the synchrotron changes from 0.3 Mc/sec to 9.6 Mc/sec.

* Now with the High Voltage Engineering Corporation.

5. Statistical Mechanics of Transport. XII. The Dense Rigid Sphere Fluid. Stuart A. Rice, John G. Kirkwood, John Ross, and Robert W. Zwanzig, *Sterling Chemistry Laboratory, Yale University.*—The theory of transport in a dense fluid of rigid spheres is developed from classical statistical mechanics by the use of phase space distribution functions. A modified Maxwell-Boltzman integro-differential equation for the distribution function in μ space is derived, and the relationship of this equation to the Enskog equation is discussed. To obtain a formulation of the flux of momentum and energy solely in terms of binary collisions, it is necessary to allow the time of coarse graining to be short. The implications of this are discussed with relation to the general principles of the statistical mechanics of transport. The viscosity and thermal conductivity of the dense rigid sphere fluid are cal-

culated. The viscosity is the same as that first calculated by Enskog, but, because of differences between the rigorous equation derived herein and the Enskog equation, the thermal conductivity differs from that computed by Enskog.

6. Nuclear Quadrupole Coupling of B^{11} in Ionic Crystals.* J. G. O'KEEFE, A. H. SILVER, AND P. J. BRAY, *Brown University.*—The nuclear magnetic resonance of B^{11} has been observed in polycrystalline $NaBF_4$ and NH_4BF_4. A Pound-Watkins recording spectrometer was used to study the line shape. The B^{11} resonance in orthorhombic[1] NH_4BF_4 shows a quadrupole splitting with a tentative value of 198 kcps for the quadrupole coupling constant, eqQ. The B^{11} resonance in $NaBF_4$ shows a much smaller quadrupole splitting with a tentative value of 100 kcps for the quadrupole coupling constant. This is to be expected as the $NaBF_4$ structure is more nearly cubic. Comparison of the quadrupole splittings of the B^{11} resonance in NH_4BF_4 will be made with the splitting observed[2] in KBF_4. The structure of the latter compound is isomorphous with that of NH_4BF_4.

* Research supported by the National Science Foundation and the U. S. Atomic Energy Commission under contract.
[1] Wyckoff, *Crystal Structures* (Interscience Publishers, Inc., New York, 1951).
[2] P. J. Bray and A. H. Silver, Bull. Am. Phys. Soc. Ser. II, 1, 323 (1956).

7. Pure Quadrupole Resonances in Chlorosilanes.* S. MOSKOWITZ AND P. J. BRAY, *Brown University.*—The pure quadrupole transition frequencies of the Cl^{35} nucleus in various solid chlorosilanes have been measured with a self-quenching super-regenerative spectrometer. These transition frequencies are proportional to the electric field gradients produced at the nuclei, to a major extent, by the bonding electrons. Comparison of the measured transition frequencies for different molecules can suggest appropriate bond structure. The structures employed[1] to explain the decrease in transition frequencies from various methyl chlorides to the corresponding chlorosilanes are appropriate in analyzing the chlorosilanes reported here. The new data, measured at 77°K are: hexachlorodisilane 19.319, 19.287, and 19.271 Mcps; dimethyldichlorosilane 17.756 Mcps; trichlorosilane 19.163, 19.030, and 18.917 Mcps; phenyl trichlorosilane 19.148 Mcps; vinyl trichlorosilane 19.316, 19.119, and 18.962 Mcps. The ratios of the transition frequencies of five chlorocarbon compounds[2,3] to their corresponding chlorosilane fall in the range 1.96 to 2.11 with a mean value of 2.02.

* This work was supported by a grant from the National Science Foundation.
[1] J. M. Mays and B. P. Dailey, J. Chem. Phys. 20, 1695 (1952).
[2] R. Livingston, J. Phys. Chem. 57, 496 (1953).
[3] D. W. McCall and H. S. Gutowsky, J. Chem. Phys. 21, 1300 (L) (1953).

8. Neutrons from Alpha-Particle Bombardment of Aluminum.* S. YAMAMOTO AND F. E. STEIGERT, *Yale University.*—Thin targets ($\frac{1}{2}$ mg/cm^2) of aluminum were bombarded with 8-Mev alphas from the Yale cyclotron. The reaction neutrons were observed by means of their forward proton recoils in 50 μ nuclear emulsions. Angles back to 35° have been studied. The yield of neutrons was enhanced by use of a 2 mg/cm^2 Mylar radiator. Groups corresponding to the following Q values were observed: -3.53, -3.73, $-3.95(?)$, -4.12, -4.41, -4.64, -4.83, -5.12, -5.31, -5.46, and -5.84 Mev. The relative error is probably of the order of ± 0.04 Mev with a possible systematic error of the order ± 0.10, since the ground state group was not observed nor were the incident alphas simultaneously observed in this experiment. A low-intensity continuum seems to extend from the highest energy group out to about a Q of -2.4. Many of the Q values agree with those previously obtained, if all data are combined. However, there appear to be more levels than heretofore observed in any single reaction leading to the nucleus P^{30}. Because of the low yield, the statistics are still rather poor, although agreement among the various angles is excellent except for the group noted.

* This work was supported in part by the Office of Naval Research.

9. Pinch Effect and Associated Phenomena.* S. P. ZIMMERMAN AND L. S. COMBES, *Tufts University.*—Various techniques have been used to study the self-constriction of a high-current discharge in a gas at low pressure. Spectroscopic evidence for the pinch effect was found, and studies were also made using magnetic probes, a photomultiplier tube, and a pulsed image converter. The results of these studies are discussed briefly.

* This work has been sponsored by the Geophysics Research Directorate of the Air Force Cambridge Research Center, Air Research and Development Command, under contracts.

MINUTES OF THE SPRING MEETING OF THE OHIO SECTION OF THE AMERICAN PHYSICAL SOCIETY, HELD AT BOWLING GREEN STATE UNIVERSITY, BOWLING GREEN, OHIO, APRIL 19–20, 1957

THE regular spring meeting of The Ohio Section of The American Physical Society was held as a joint session with Section E: Physics and Astronomy, of Ohio Academy of Science. This is the usual practice.

Friday morning, April 19, was devoted to viewing and to judging the 196 high-school projects entered in the physics category of the Junior Academy program. This seems to be one way our group may help get acquainted with high-school students, and may help attract them into the field of physics. The Friday afternoon program consisted of papers which dealt with high-energy physics and were as follows:

Theoretical Considerations in High-Energy Physics. L. S. KISSLINGER, *Western Reserve University.*

Our Misty Mesic Horizon. MARIAN L. POOL, *The Ohio State University.*

Interactions of Gamma Rays with Matter. E. S. GREGG, *Case Institute of Technology.*

Saturday morning, April 20, was devoted to contributed papers, abstracts of which follow. At the business session, the following officers were chosen for the year 1957–1958. *Chairman*, Wendell R. Koch, Wright Air Development Center, Wright-Patterson Air Force Base, Ohio; *Vice-Chairman*, Howard N. Maxwell, Ohio Wesleyan University, Delaware, Ohio; and *Secretary-Treasurer*, Leon E. Smith, Denison University, Granville, Ohio.

LEON E. SMITH, *Secretary*
Ohio Section

1. Amplitude Characteristics of Radio Reflections from Meteors. LLOYD R. WYLIE, *Wittenberg College*, AND HORACE T. CASTILLO, *Wright Air Development Center, Wright-Patterson Air Force Base.*—Meteors striking the upper atmosphere of the earth produce ionization columns that can be used as reflectors of radio transmissions. The 15- and 20-Mc transmissions of the National Bureau of Standards radio station WWV in Washington, D. C., have been recorded in Springfield, Ohio, where the communication path was provided by meteor trails. Duration and amplitude of a burst is related to a particular meteor trail. Previous work has indicated that meteoric bursts occur in clusters. This paper describes the duration and amplitude characteristics. Durations less than 0.5 sec predominate. Amplitudes less than 0.2 microvolt predominate in the 20-Mc transmission and are generally less than 1 microvolt in the 15-Mc transmission.

2. Vapor Pressure of Potassium Chloride in the Region 0–15 mm of Mercury by the Boiling Point Method. THOMAS R. VOGT AND THOMAS S. SMITH, *Physics Department, Ohio University.*—By means of the boiling point method, the vapor pressure of potassium chloride has been measured in the temperature range of 831°C to 999°C. From the 31 observations made in this region, the equilibrium curve may be expressed as $\log P = -(9620/T)+8.746$, yielding a heat of vaporization $\Delta H_{vap}=43\,940$ cal/mole. The melting point has also been observed at 770 ± 0.5°C.

3. Validity of a Perturbation Treatment of the Quadrupole Levels of Sodium Chlorate.* PAUL M. PARKER,† *The Ohio State University.*—A fifth-order perturbation treatment of the Cl^{35} quadrupolar energy levels of sodium chlorate[1] has been re-examined in the light of a more recent numerical treatment[2] of quadrupolar energy levels in single crystals. This examination ascertained that the fifth-order perturbation treatment is substantially valid, even though poor convergence is involved in some of the perturbation coefficients. From this it is concluded that the coupling constants quoted for sodium chlorate are correct but that the limits of error quoted for the effective nuclear magnetic dipole moment more appropriately should be ±0.0002 nuclear magneton.

* This work was supported in part by a contract between the Office of Scientific Research of the Air Research and Development Command, Baltimore, Maryland, and The Ohio State University Research Foundation.
† General Electric Fellow 1956–1957.
[1] Ting, Manring, and Williams, Phys. Rev. 96, 408 (1954).
[2] P. M. Parker, J. Chem. Phys. 24, 1096 (1956).

4. Approximate Treatment of the Distance Function of a Beta Backscatter Thickness Gauge.* PHILIP A. MACKLIN, *Miami University.*—Beta backscatter thickness gauges are used to measure the thickness of one material coated on a substrate sufficiently thick for saturation backscattering. Differences in Z^3 between the coating and substrate make the amount of backscattering dependent upon the coating thickness. The usual gauge geometry has azimuthal symmetry and may be approximated by a disk source, a beta opaque shadow disk, and an annular ring ionization chamber at different axial positions. By simple geometric arguments one sees that there will be a gauge to scatterer distance at which the response will be a maximum. Thus a variation in distance, as well as a change in coating thickness, will cause a change in response. Various approximations to the distance function will be presented, as well as the effects of design parameter variations in these approximations on the location and flatness of the response maximum. Finally, a "stagger-tuned" geometry will be presented as one possible modification of the gauge geometry to improve the flatness of the response maximum.

* Based on work done in 1955 as a summer research employee of Armco Steel Corporation, Middletown, Ohio.

5. Nuclear Orientation of Co^{58} and Co^{60}—Treatment of Experimental Data. DAVID F. GRIFFING, *Miami University.*—Radioactive Co^{58} and Co^{60} are grown in the same single crystal and cooled to approximately 0.03°K by adiabatic demagnetization. The counting rates resulting from the 0.805-Mev gamma ray from Co^{58} and the 1.17-Mev gamma ray from Co^{60} are observed with a scintillation spectrometer as a function of magnetic temperature and angle. The analysis of this experimental data is discussed. Treated in particular are problems of curve fitting, the assignment of errors to both the final and intermediate results, a search for and elimination of systematic errors, and several practical techniques useful in treating experimental data.

6. Isotopic Spin and Nucleon Isobar Models.* J. A. EISELE, *The Ohio State University* (introduced by J. D. Kurbatov).—The conventional isotopic spin formalism which described the nucleons as particles with $T=\frac{1}{2}$ has been extended to the system of four particles, the two nucleons plus two antinucleons. There appears to be some asymmetry in the treatment of the proton and the neutron, and, since the formalism may be arbitrary, it seems reasonable to investigate the consequences of some alternate formalism. Because of the added freedom resulting from the "strangeness" quantum number, a conclusion could not be reached without investigating the simplest integral $T=1$, $M_t=+1$, 0, -1, and half-integral $T=\frac{3}{2}$, $M_t=\frac{3}{2}$, $+\frac{1}{2}$, 0, $-\frac{1}{2}$, $-\frac{3}{2}$ spin assignments. With this in mind, the π meson with $T=1$, $M_t=+1$, 0, -1 was combined vectorially with each of the foregoing nucleon models, and then cross sections for scattering π mesons at hydrogen (protons) were calculated in the region of the low-energy resonance. The conventional formalism predicts the ratio of the cross sections for direct π^+ to charge exchange π^- to direct π^- scattering to be 9:2:1. The formalism with $T=1$ predicts that the ratio of cross sections would be $9:\frac{1}{2}:1$. The formalism with $T=\frac{3}{2}$ predicts these same cross sections to be in the ratio 9:2:16 or 4:2:1. It was found that only the first or conventional formalism gives answers in agreement with experiment.

* Assisted by the U. S. Atomic Energy Commission.

7. Neutron Slowing-Down Time Studies. FRED HOLZER, *Case Institute of Technology.*—Neutron capture cross-section measurements may be made using a multi-channel delay analyzer together with a heavy moderator. In preparation for such measurements, data on the time necessary for Po-Be neutrons to slow down in graphite to the cadmium resonance have been taken. The result of a preliminary analysis of these data will be given. Design parameters for a slowing-down-time spectrometer using a lead moderator and a pulsed photoneutron source will also be presented.

8. Bremsstrahlung Measurements. PARK FRENCH, *Case Institute of Technology.*—Measurements were made with a Compton spectrometer to determine the shape of the upper end of the bremsstrahlung spectra from thin and thick targets. Data reduction is not yet complete, but thin target data indicate that the spectral curve enters the high-energy intercept with finite slope. Thick target measurements in the forward direction show complete agreement with thin target measurements, and both show fair agreement with the Schiff spectrum. Off-axis thick target measurements were made, showing an easily discernible change in spectral shape. Preliminary calculations show the relationship between the thin target spectrum and both thick target spectra to be in good agreement with theory.

Minutes of the 1957 Spring Meeting of the New York State Section Held at Hamilton College, Clinton, New York, on Friday and Saturday, May 3 and 4, 1957

THE thirty-seventh meeting of the New York State Section was held at Clinton, New York, with Hamilton College acting as host to about 40 registrants. The Friday afternoon session was followed by a dinner at the Alexander Hamilton Inn. The after-dinner Speaker was Dr. William F. Neuman, Director of the Atomic Energy Project at the University of Rochester. The lecture was entitled "Problems of Strontium-90 Fallout."

An election of officers and members of the Executive Committee was held at the Business Meeting. The names of the officers and members of the Executive Committee who will serve during the two-year period 1957–1959 are listed below:

Chairman: G. W. Hazzard, General Electric Company

Vice-Chairman: T. S. Renzema, Clarkson College

Secretary-Treasurer: O. E. Miller, Eastman Kodak Company

Executive Committee:

H. E. Way, Union College
Miss M. Healea, Vassar College
K. H. Moore, RPI.
M. J. Pryor, Albany State College
D. H. Tomboulian, Cornell University

The titles of invited papers presented during two sessions are given below:

1. **Thermoelectric Energy Conversion—A Review.** W. J. Van der Grinten, *General Electric Company.*
2. **Magnetic Resonance Studies of Electron-Nucleus Interactions in Solids.** D. H. Holcomb, *Cornell University.*
3. **Application of Digital Computers to the Solution of Scientific and Engineering Problems.** F. M. Staudaher, *General Electric Company.*
4. **Element Synthesis by Neutron Capture.** P. Fong, *Utica College of Syracuse University.*
5. **How Iron Magnetizes.** C. P. Bean, *General Electric Company.*
6. **Infrared Techniques Applied to Military and Commercial Equipment.** A. H. Canada, *General Electric Company.*

Professor G. Harvey Cameron, Chairman of the Physics Department at Hamilton College, was in charge of the program and local arrangements.

D. H. Tomboulian, *Secretary*
New York State Section

New Members of the American Physical Society

The following are names of those elected to Fellowship and Membership at the Washington meeting of the American Physical Society on April 24, 1957.

The Proceedings of the Washington meeting will be published in a later issue of the Bulletin.

Elected to Fellowship: B. M. Abraham, L. T. Aldrich, R. M. Badger, William Band, W. E. Bennett, C. K. Bockelman, L. M. Bollinger, W. B. Cheston, W. A. Chupka, J. D. Cobine, Fritz Coester, M. Y. Colby, W. C. Dunlap, Jr., J. E. Evans, W. M. Fairbank, K. W. Ford, Simon Freed, M. S. Freedman, E. W. Friesen, C. G. B. Garrett, Nathan Ginsburg, A. E. S. Green, G. K. Groetzinger, C. L. Hammer, S. S. Hanna, J. A. Harvey, R. J. Hayden, W. J. Henderson, D. C. Hess, C. T. Hibdon, R. H. Hildebrand, N. M. Hintz, J. G. Hoffman, W. F. Hornyak, V. W. Hughes, Leon Katz, Carl Kenty, Chihiro Kikuchi, W. C. Koehler, P. G. Koontz, Dieter Kurath, R. T. Lagemann, E. E. Lampi, E. G. Linder, R. E. Meyerott, D. W. Miller, J. E. Nafe, R. G. Newton, T. B. Novey, R. D. O'Neal, G. J. Perlow, E. W. Pike, W. G. Proctor, Sol Raboy, E. G. Ramberg, J. M. Reynolds, G. R. Ringo, Fritz Rohrlich, Philip Rosen, M. H. Ross, W. T. Scott, K. L. Sherman, S. F. Singer, R. C. Spencer, S. T. Stephenson, C. P. Swann, M. M. Ter-Pogossian, A. V. Tollestrup, D. MacP. Van Patter, G. M. Volkoff, Aristid von Grosse, A. W. Waltner, D. T. Warren, Bernard Weinstock, P. B. Weisz, M. K. Wilkinson, and Herman Yagoda.

Elected to Membership: Benjamin Abeles, •Lewis E. Agnew, Jr., Torsten Alvăger, •Le Tuan Anh, •Thomas E. Bartha, Enrico G. Beltrametti, Kent Berge, Karl-Erik Bergkvist, •Georges J. Bessis, •Bernard L. Bloch, •Sylvan C. Bloch, J. H. Bodine, Jr., Harold C. Box, Howard B. Briggs, Lewis Brotman, Walter Stephen Byrnes, Salvatore P. Carfagno, •Robert L. Carovillano, •Winston A. Cartledge, William H. Charry, K. Walker Chidsey, Jr., •Harry J. Christoffers, Forrest Pierce Clay, Jr., Shepard Anthony Clough, •Barry G. Cohen, Melvin S. Cohen, •Franklin P. Dixon, Klaus Dransfeld, •Irwin M. Feldman, •Niles C. Fernelius, Charles Ernest Francis, Thurmond M. Francis, •Jerry D. Fuller, •Emerson G. Funk, Jr., Leonard Burton Gardner, II, •Robert Harry Gersten, Harry F. Gilmore, Jr., Frederick Gordon, Jr., Rudolf Haas, •William Halprin, Glenn G. Havens, Volker Heine, Gerald S. Heller, •Jackson Rea Herring, Larry Leigh Higgins, Adolf Rudolf Hochstim, Ladis D. Kovach, •Jay F. Kunze, G. J. F. Legge, •Shin-R Lin, Willy R. Linett, Hugh Montgomery Long, Arthur Lubin, Arthur C. Lucas, •Edward M. MacKinnon, Jurij Maczuk, Lynn H. Matthias, Robert C. McMillan, Guy R. Mesnard, •Richard W. Michie, •Roger Edward Mills, Clifford Eugene Morgan, •Daniel F. Morgan, Jr., Phillip A. Newman, Jr., Henryk Niewodniczanski, Ken Nobe, •Gerald J. O'Halloran, •Kazem Omidvar, •James Evans Parker, John Greenhalgh Parker, •Gordon V. Pefley, Jr., William T. Pinkston, •Herman Postma, John L. Power, Glenn F. Powers, Augustus Prince, George R. Preuett, Harry F. Remde, Jr., Paul E. Ritt, James M. Robinson, Jr., Yehuda L. Sandler, William F. Schmitt, Walter L. Seibyl, Jr., Dennis F. Shaw, Alexander Sherman, A. E. Siegman, Bob H. Smith, Donald Oscar Smith, •Archie L. Stamper, Walter L. Starr, Gherardo Stoppini, •Stephen L. Strong, •Philip Henry Sutter, Michael Svonavec, •L. Wayne Swenson, •Sandra Ruth Tausig, Joseph J. Urbanetti, •Robert Vandenbosch, K. Vedam, Weston E. Vivian, George H. Wagner, •John J. Wahl, •Charles Warner, III, Basil Weir, B. G. Whitmore, Donald E. Willig, Brian Graham Wilson, •Donald C. Wold, Karhryn J. Wood, Harold W. Wyckoff, •Anthony Zizmont, and Jacob W. Zwick.

• Student.

The American Physical Society

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Treasurer	S. L. QUIMBY	Columbia University
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Past Presidents now on Council: W. F. G. Swann, H. A. Bethe, R. T. Birge, and E. P. Wigner.

Elected Members of the Council: John Bardeen, A. O. Nier, F. Seitz, A. M. Weinberg, S. K. Allison, N. F. Ramsey, Walker Bleakney, and W. K. H. Panofsky.

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